APPENDIX 1

US DOT/FAA Specification FAA-C-1217f

Electrical Work, Interior

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FAA-C-1217f
February 26, 1996
SUPERSEDING
FAA-C-1217e,

US DEPARTMENT
01/25/91
OF TRANSPORTATION
Federal Aviation
Administration

U. S. Department of Transportation
Federal Aviation Administration
Specification

ELECTRICAL WORK, INTERIOR

FORWARD

This document has been revised to reflect current technology changes and to incorporate the latest commercial standards.

1. SCOPE

1.1 Scope.- This specification covers the ***minimum requirements*** for electrical work at FAA facilities. Where the phrase "unless otherwise indicated" or similar wording appears, it refers exclusively to other documents that are specific parts of the contract. Where there are requirements peculiar to specific FAA facility types, e.g., air route traffic control centers (ARTCCs), metroplex control facilities (MCFs), terminal radar control (TRACONs), etc., these requirements will be added following the appropriate paragraph.

2. APPLICABLE DOCUMENTS

2. APPLICABLE DOCUMENTS.- The current issues of the following documents in effect on the date of the invitation-for-bids or request-for-proposals form a part of this specification, and are applicable to the extent specified herein.

2.1 Federal specifications

J-C-30	Cable and Wire, Electrical (Power, Fixed Installation)
W-C-375	Circuit Breakers, Molded Case; Branch Circuit and Service
W-F-414	Fixture, Lighting (Fluorescent, Alternating Current, Pedant Mounting)
W-L-305	Light Set, General Illumination (Emergency or Auxiliary)
W-P-115	Panel, Power Distribution
WW-C-566	Conduit, Metal, Flexible
QQ-W-343	Wire, Electrical, (uninsulated)

(To obtain copies of federal specifications, contact General Services Administration offices in Washington DC, Atlanta, Boston, Chicago, Dallas, Denver, Kansas City MO, Los Angeles, New York, San Francisco, or Seattle.)

2.2 Steel Structures Painting Council standards

SSPC-PS 10.01 Hot-Applied Coal Tar Enamel Painting System

(Single copies of SSPC Standards can be obtained from the Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, Pa 15213, 412/578-3327)

2.3 Federal Aviation Administration specification/standards/orders

FAA specification:

FAA-C-1391 Installation and Splicing of Underground Cables

FAA standards:

FAA-STD-019 Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities

FAA-STD-020 Transient Protection, Grounding, Bonding and Shielding Requirements for Electronic Equipment

FAA orders:

3900.49 Control of Hazardous Energy During Maintenance, Servicing and Repair

6950.19 Practices and Procedures for Lightning Protection, Grounding, Bonding and Shielding Implementation

6950.20 Fundamental Consideration of Lightning, Protection, Grounding, Bonding and Shielding

6950.22 and	Maintenance of Electrical Power Control Cables
6950.27	Short Circuit Analysis and Protective Device Coordination Study

(Copies of FAA specifications may be obtained from the Contracting Officer in the office issuing the invitation-for-bids or request-for-proposals. Requests should fully identify material desired, i.e., specifications, standard, amendment, and drawing numbers and dates. Requests should cite the invitation-for-bids, request-for-proposals, or the contract involved or other use to be made of the requested material.)

2.4 National Fire Protection Association (NFPA) publications

NFPA 70	National Electrical Code (NEC)

(Requests for copies of NFPA publications should be addressed to the National Fire Protection Association, Batterymarch Park, Quincy MA 02269.)

2.5 National Electrical Manufacturers Association (NEMA) standards

OS-1	Sheet Steel Outlet Boxes, Device Boxes, covers and Box Supports
MG-1	Standard for Motors and Generators
ST 20	Dry Type Transformers for General Applications
VE 1	Cable Tray Systems
WC 5	Thermoplastic Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

WD 1	General Requirements for Wiring Devices

(For copies of NEMA standards, contact the National Electrical Manufacturers Association, 2101 L Street N.W. Washington DC 20057, 202/457-8400.)

2.6 Underwriters' Laboratories (UL) Inc. standards

UL 5	Surface Metal Raceways and Fittings
UL 6	Rigid Metal Conduit
UL 50	Enclosures for Electrical Equipment
UL 486A	Wire Connectors and Soldering Lugs for Use with Copper Conductors
UL 486C	Splicing Wire Connectors
UL 486E	Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors
UL 514A	Metallic Outlet Boxes
UL 514B	Fittings for Conduit and Outlet Boxes
UL 542	Lampholders, Starters, and Starter Holders for Fluorescent Lamps
UL 651	Schedule 40 and 80 Rigid PVC
UL 797	Electrical Metallic Tubing
UL 870	Wireways, Auxiliary Gutters and Associated Fittings
UL 935	Fluorescent-Lamp Ballasts
UL 1242	Intermediate Metal Conduit

(For copies of UL standards, contact Underwriters' Laboratories Inc., Publication Department, 333 Pfingsten Rd., Northbrook IL 60062.)

2.7 Institute of Electrical and Electronics Engineers (IEEE) Inc. standards

STD C57.12.80	Standard Terminology for Power Distribution Transformers
STD 141	Recommended Practice for Electric Power Distribution for Industrial Plants
STD 519	Recommended Practices and Requirements for Harmonic Control and Electrical Power Systems
STD 1100	Recommended Practice for Powering and Grounding Sensitive Electronic Equipment

and

For copies of this standard, contact the IEEE Inc., Service Department, 445 Hoes Lane, PO Box 1331, Piscataway NJ 08855-1331.)

2.8 Other documents

2.8.1 Local utility companies.- The rules and regulations of the local utility companies providing service.

2.8.2 Local governing bodies.- The rules, regulations, and codes of local governing bodies.

3. MATERIALS

3.1 General.- The contractor shall furnish all materials not specifically identified as Government Furnished Materials in the invitation-for-bids or contract. Materials and equipment shall comply with all requirements of the contract documents. Materials furnished by the contractor shall be new, the standard products of manufacturers regularly engaged in the production of such materials, and of the manufacturer's latest designs that comply with the specification requirements. If materials and equipment requirements conflict, the order of precedence for selection shall be as follows: special contract provision, the contract drawings, this specification, and then continuing order of precedence, referenced FAA documents, Military documents, Federal specifications, NFPA publications, IEEE standards; UL standards and NEMA standards. Wherever standards have been established by Underwriters' Laboratories, Inc., the material shall bear the UL label.

4. INSTALLATION

NOTE: Unscheduled interruptions of the electrical service to FAA facilities may cause aircraft accidents and loss of life. Work requiring a temporary or permanent deenergization of equipment shall be scheduled in writing with the onsite FAA maintenance personnel. Only onsite FAA maintenance personnel are authorized to energize, deenergize equipment or to operate a circuit breaker, switch, or fuse in an FAA facility. Work procedures shall include lock-out/tag-out procedures in accordance with FAA Order 3900.49.

4.1 General.- The rules, regulations and reference specifications enumerated herein shall be considered as minimum requirements. FAA requirements often exceed those of other standards organizations such as the NEC. Adherence to other standards shall not relieve the contractor from furnishing and installing higher grades of materials and workmanship when so required by this specification. Adherence to this specification shall not relieve the contractor from furnishing and installing higher grades of materials and workmanship when so required by the contract drawings or special contract provisions. This specification shall govern when conflicts occur between it and the documents referenced in paragraph 2, Applicable documents, and in the order of precedence established in paragraph 3, Materials.

4.1.1 Short circuit analysis and protective device coordination (SCA/PDC). - The distribution system and all component parts, when installed or as modified, shall be in accordance with IEEE Standard 519, Recommended Practices and Requirements for Harmonic Control and

Electrical Systems, and shall include a short circuit analysis and protective device coordination study in accordance with FAA Order 6950.27.

4.2 Workmanship.- All materials and equipment shall be installed in accordance with the contract drawings. When manufacturers recommended installation methods conflict with contract requirements, differences shall be resolved by the Contracting Officer. The installation shall be accomplished by qualified workers regularly engaged in this type of work. Where required by local regulations, the workers shall be properly licensed.

4.3 Contract drawings.- Where the electrical drawings indicate (by diagram or otherwise) the work intended and the functions to be performed, even though some details are not shown, the contractor shall furnish all equipment, material (other than the Government-furnished items, see paragraph 3.1) and labor to complete the installation work and to accomplish all the indicated functions of the electrical installation. Further, the contractor shall be responsible for taking the necessary actions to ensure that all electrical work is coordinated and compatible with architectural, mechanical, and structural plans, and the layout of any special electronic equipment.

4.3.1 Minor departures.- Minor departures from exact dimensions shown on the electrical plans may be permitted when required to avoid conflict or unnecessary difficulty in placement of a dimensioned item, provided all contract requirements are met. The contractor shall promptly obtain approval from the Contracting Officer prior to undertaking any such departure and shall provide appropriate documentation of the departure.

4.4 Grounding

4.4.1 General.- FAA grounding requirements often exceed those of the NEC. Grounding systems shall be as indicated on the contract drawings and as specified herein. Reference IEEE Standard 1100-1992, Recommended Practice for Powering and Grounding Sensitive Electronic Equipment, when installing all NAS equipment. In no case, however, shall the NEC be violated.

4.4.2 Grounding electrode conductor.- The grounding electrode conduct shall be bare or insulated copper and shall be sized as shown in the contract documents. When not indicated in the contract documents, the conductor shall be copper and sized in accordance with Table 250-94, "Grounding Electrode Conductor for AC Systems", of the NEC, except that the conductor shall not be smaller than No. 6 AWG. Where the grounding electrode conductor is routed through a metal raceway, the raceway shall be electrically continuous and bonded to the conductor at each end. The grounding electrode conductor shall be bonded to the earth electrode system with an exothermic welded joint. For a separately derived system such as an isolation transformer, the grounding electrode conductor shall be connected in accordance with the NEC. This conductor shall be permitted to terminate by exothermic welding to an equipment room's perimeter ground cable under a raised floor.

4.4.3 – Earth electrode system.- The earth electrode system shall be installed as shown in the contract documents. Unless otherwise indicated in these documents, the earth electrode system shall consist of a minimum of four (4) ground rods located at the corners of a structure. Rods shall be spaced apart a distance equal to or greater than the length of the rods. Ground rods shall be 3/4 inch by 10 feet, copper or copper-clad steel. Sectionalized type or exothermic butt welded rods shall be used when deeper earth penetration is required. Rods shall be interconnected by a bare copper cable forming a closed loop around a structure. The cable shall be a minimum No. 4/0 AWG and shall be buried at least 2 feet below grade. The top of the vertically-driven ground rods shall be a minimum of 12 inches below grade. All underground metal pipes (excluding gas piping systems), tanks, and the telephone ground, if present, shall be connected to the earth electrode system by a copper cable no smaller than No. 2 AWG. All underground connections shall be made by exothermic welding process unless otherwise indicated.

4.4.4 Earth electrode system resistance.- The resistance of the earth electrode system shall not exceed 10 ohms, as tested per paragraph 5.3.6, unless otherwise indicated. If the measured resistance exceeds 10 ohms, the Contracting Officer shall be notified immediately for further guidance.

4.4.5 Equipment grounding conductor

4.4.5.1 General.- All metallic non-current carrying parts of electrical equipment shall be grounded with equipment grounding conductors whether or not shown on the drawings. Equipment grounding conductors shall always be green insulated copper conductors unless otherwise indicated. Non-insulated equipment grounding conductors are not allowed. When these conductors are not sized, or shown on the contract drawings, they shall be sized in accordance with Table 250-95, "Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment", of the NEC.

4.4.5.2 Connections.- There shall be no interconnection between equipment grounding conductors and neutral conductors except at the main service and separately derived sources. All connections to equipment to be grounded shall be made with a grounding connector specifically intended for that purpose. Bare wire, wrapped around mounting bolts and screws, is not acceptable as a grounding connection. All ground lugs shall be of a noncorrosive material suitable for use as a grounding connection, and must be compatible with the type of metal being grounded. All mating surfaces and connections shall be between cleaned bare metal to bare metal surfaces.

4.4.5.3 Installation.- Each overcurrent device shall have its own equipment grounding conductor, i.e., a single-pole single-phase overcurrent device shall be supplied with an equipment grounding conductor; a two-pole, single-phase overcurrent device shall be supplied with its own equipment grounding conductor; a three-pole, three-phase overcurrent device shall be supplied with its own equipment grounding conductor. The equipment grounding conductor shall be installed in the same conduit as its related branch and feeder conductors and shall be connected to the ground bus in the branch or distribution panelboard. Metal conduit housing the equipment grounding conductor shall be electrically continuous, forming a parallel path to the equipment grounding conductor, except as allowed by the NEC. Where parallel feeders are installed in more than one raceway, a full sized equipment grounding conductor shall be installed in each raceway.

4.4.6 Raceway grounding.- Surface metal raceways, wireways, or cable rack systems shall be installed in a manner that assures electrical continuity. Insulated copper bonding jumpers shall be installed between adjacent raceway sections to assure proper bonding. Uninsulated conductors shall not be used. Unless otherwise indicated, the minimum size for these bonding jumpers shall be No. 6 AWG. Where aluminum raceways are used, the jumpers shall be bonded with approved connectors for the dissimilar metals. All metallic raceway penetrations into a facility structure shall be bonded to the earth electrode system in accordance with FAA-STD-019.

4.4.7 Other grounding systems.- Any additional grounding systems used for electronic equipment shall be connected directly to the exterior earth electrode system or the perimeter ground cable under a raised floor in an equipment room. Other grounding systems shall not be used in place of the equipment grounding conductor system. The conductor used for other grounding (i.e., NEC 250-74, exception #4) systems shall be color coded green with a yellow stripe for single point isolated signal ground, green with an orange stripe for multipoint signal ground, green with a red stripe for high energy ground, green with a violet stripe for isolated equipment grounding connections.

4.5 Electrical surge protection

4.5.1 General.- All electrical surge protection systems shall be installed in accordance with FAA-STD-019.

4.5.2 Supply transformer.- For utility owned transformers, protective devices shall be at the discretion of the utility. For FAA—owned transformers, proper protection shall be provided on the primary side of the transformer.

4.5.3 Service entrance surge arrester.- A fused surge arrester provided with disconnect capability shall be installed on the line, (supply-side) of the service as close as possible to the service terminals. Separate terminating lugs shall be provided for the surge arrester. This arrester shall be compatible with the service voltage, and shall be wired to avoid loops, sharp bends and kinks, and to minimize the number of bends. There shall be no interconnection between neutral and ground within the arrester. Arrester conductors shall be No. 4 AWG insulated copper or larger, unless a smaller size is recommended by the arrester manufacturer.

4.5.4 Transient suppression installations.- Where transient suppression devices are installed in the electrical power distribution system they shall be installed in accordance with manufacturers instructions unless otherwise specified.

4.5.5 Land line/cable penetration installations.- Suppression systems shall be provided for land line and cable penetration systems in accordance with FAA-STD-019. High energy grounding conductors shall be bonded directly to the earth electrode system or to the perimeter ground cable under raised floors in equipment rooms.

4.6 Wiring methods

4.6.1 General.- All wiring shall consist of insulated copper conductors installed in metallic raceways, unless otherwise specified.

4.6.1.1 Conductor routing.- Panelboards, surge arresters, disconnect switches, etc., shall not be used as raceway for conductor routing other than conductors that originate or terminate in these enclosures. Isolated ~~ground~~ conductors will be allowed to traverse these enclosures.

4.6.1.2 Conductor separation - Power conductors shall be routed separately from all other conductor types. This may be accomplished by routing power conductors and other conductors in separate raceways, or by a metallic divider between the power conductors and the other conductors in the same raceway.

4.6.2 Neutral conductor.- Shared/common neutrals shall not be permitted, i.e., each overcurrent device shall have its' own separate neutral conductor. Neutral conductor sizes shall not be less than the respective feeder or phase conductor sizes.

4.6.3 Raceway systems

4.6.3.1 General.- Each run shall be complete, and shall be fished and swabbed before conductors are installed. Ends of raceway systems not terminated in boxes or cabinets shall be capped. Exposed raceways shall be installed parallel to or at right angles with the lines of the structure. Crushed or deformed raceways shall not be installed. A pull wire shall be installed in all empty tubing and conduit systems in which wiring is to be installed by others. The pull wire shall be No. 14 AWG zinc-coated steel, or plastic with a minimum 200-pound tensile strength. Ten inches of slack shall be left at each end of the pull wire. Sections of raceways which pass through to damp, concealed, or underground locations shall be of a type allowed for such locations by NEC Article 300-5, and shall extend a minimum of 12 inches beyond the damp, concealed, or underground area. Where raceway has to be cut in the field, it shall be cut square and burrs and sharp edges removed. Where conduits penetrate walls or floors separating the building interior from the exterior, they shall be sealed to prevent moisture and rodent entry and to deter air transfer. In addition, where conduits penetrate walls separating individually controlled temperature or humidity controlled areas, they shall be sealed to prevent air circulation. Sealing methods and sealants shall be accordance with NEC Article 300-7. Openings around penetrations through fire-resistant-rated walls, partitions, floors, or ceilings shall be fire stopped using approved methods to maintain the fire resistance rating.

4.6.3.2 Conduit. – Minimum conduit size shall be 3/4 inch unless otherwise specified. Conduit for telephone and signal systems shall be allowed to be 1/2 inch. Where threads have to be cut on conduit, the threads shall have the same effective length and shall have the same thread dimensions and taper as specified for factory cut threads on conduit.

NOTE:

For ARTCCs, MCFs, and Large TRACONs, rigid steel conduit (RSC)or intermediate metal conduit (IMC) shall be used for all distribution panel feeders, transformer feeders, motor control center feeders and distribution switchboards. Electrical metallic tubing (EMT) maybe used for communication, lighting and branch circuits.

4.6.3.2.1 Zinc coated rigid steel conduit (RSC).- Zinc coated rigid steel conduit (RSC) shall conform to UL 6. RSC, may be used in all locations and shall be used for all underground service conductors. For installation below slab, on-grade, or underground, the conduit shall conform to Steel Structures Painting Council Standard, SSPC-PS 10.01, or shall be field wrapped with 0.01-inch thick pipe wrapping plastic tape applied with 50% overlap. Fittings used underground shall be protected by field wrapping as specified herein for conduit. All fittings used with rigid steel conduit shall be the threaded type, of the same material as the conduit. Where conduits enter enclosures without threaded hubs, double locknuts (one on each side of the enclosure wall) shall be used to securely bond the conduit to the enclosure. In addition, a bushing shall be installed on the interior threaded end of the conduit to protect conductor insulation.

4.6.3.2.2 Intermediate metal conduit (IMC). IMC shall be zinc coated steel, shall conform to UL Standard 1242, and shall bear the UL label. For installation below slab on grade or underground, the conduit shall conform to Steel Structures Painting Council Standard, SSPC-PS 10.01, or shall be field wrapped with 0.01-inch thick pipe wrapping plastic tape applied with 50% overlay. Fittings used underground shall be protected by field wrapping as specified herein for conduit. Where it is necessary to fabricate IMC bends in the field, the tooling required to fabricate those bends shall be specifically designed for IMC. All fittings shall be of the threaded type, of the same material as the conduit. Where conduits enter enclosures without threaded hubs, double locknuts (one on each side of the enclosure wall) shall be used to securely bond the conduit to the enclosure. In addition, a bushing shall be installed on the interior threaded end of the conduit to protect conductor insulation.

4.6.3.2.3 Electrical metallic tubing (EMT).- EMT shall conform to UL 797. EMT may be used only in dry interior locations, and where not subject to physical damage. EMT shall not be used on circuits above 600 volts nor in sizes greater than 34 inches in diameter. Fittings used with EMT shall be standard compression-type fittings designed for this type of EMT, unless otherwise indicated. Screw-type fittings are not acceptable. Where EMT enters enclosures without threaded hubs, an appropriate connector with threads and cast or machined (not sheet metal) locknut shall be used to securely bond the conduit to the enclosure. The connector body and locknut shall be installed so that firm contact is made on each side of the enclosure. In addition the connectors shall have an insulated-throat, smooth bell shaped end, or a bushing.

4.6.3.2.4 Rigid aluminum conduit.- Aluminum raceways shall not be used for any installation.

4.6.3.2.5 Rigid nonmetallic conduit.- Rigid nonmetallic conduit shall be heavywall PVC conforming to UL 651. Rigid nonmetallic conduit used to protect electrical power conductors may only be used underground, or in concrete, or as a vertical riser to 6 inches above grade or floor surface for connection to metal conduit; and only when required by the contract drawings or specific job specifications. PVC fittings shall be used with PVC conduit and shall be assembled in accordance with manufacturer's instructions. A PVC threaded fitting with locknut and plastic bushing shall be used to connect PVC conduit to boxes or cabinets without threaded hubs. Rigid nonmetallic conduit may be used to protect lightning protection system conductors and, in interior locations, to protect signal grounding conductors.

4.6.3.2.6 Flexible metal conduit.- Flexible metal conduit shall conform to Federal Specification, WW-C-566. Flexible metal conduit shall be used for terminal connections to motors or motor driven equipment, and in lengths only up to 6 feet for other applications permitted by the NEC. Liquid-tight flexible metal conduit shall be used outdoors and in wet locations. All flexible metal conduit shall be of a type where both the conduit and fittings are listed for grounding. This last requirement shall not apply to factory assembled equipment.

NOTE: Flexible metal conduit may be used under raised floor for branch circuits in lengths longer than 6 feet in computer room locations that meet all the requirements of Article 645 of the NEC. All fittings and junction boxes shall be liquid tight types under the raised floor.

4.6.3.2.7 Flexible nonmetallic conduit.- Flexible nonmetallic conduit shall not be used.

4.6.3.3 Surface raceways.- Nonmetallic surface raceways shall not be used. Surface metal raceways shall conform to UL 5. Surface metal raceways shall be installed only in exposed, dry locations not subject to physical damage. Surface metal raceways shall meet NEC requirements, however, they shall not be used for circuits above 600 volts.

4.6.3.4 Wireways.- Wireways shall conform to UL 870. Wireways shall only be installed in accessible locations. Wireways installed in wet or outdoor locations shall be rated for these locations.

4.6.3.5 Cable rack systems

4.6.3.5.1 General.- Cable rack systems shall be of the ladder or ventilated trough type conforming to NEMA Standard VE 1, unless otherwise indicated. All components for each cable rack system shall be the product of a single manufacturer. Cable rack support spacing shall be as recommended by the manufacturer except that in no case shall spacing of supports exceed 6 feet. Cable racks shall be supported from structural members only.

4.6.3.5.2 Dimensions.- Straight sections, bends, tees, offsets, reducers, etc., for ladder-type cable rack systems shall consist of 3 inch minimum side channels with suitable cross channels (rungs) installed on 6 inch centers unless otherwise indicated. Straight sections, fittings, etc., for ventilated-type cable rack systems, shall have 3 inch minimum high sides and a ventilated bottom with cross pieces 2 inches (maximum) wide on 3 inch (maximum) centers and openings 2 inches (maximum) wide. Cable rack widths shall be as shown on the drawings.

4.6.4 Raceway support systems

4.6.4.1 General.- Raceways shall be securely supported at intervals specified in the NEC Article 300-11, "Securing and Supporting", and fastened in place with pipe straps, wall brackets, hangers, or ceiling trapezes. Fastenings shall be by wood screws, nails or screw-type nails to wood; by toggle bolts on hollow masonry units; by expansion-bolts on concrete or brick; by machine screws, welded threaded studs, or spring tension clamps on steel work. Nail type nylon anchors or threaded studs driven by a power charge and provided with lock washers and nuts may be used in lieu of expansion bolts, machine screws, or wood screws. Threaded C clamps with retainers may be used. Raceways or pipe straps depth of more than 1-1/2 inch in reinforced concrete beams, or to a depth of more than 3/4 inch in reinforced concrete joists, shall not cut the main reinforcing bars. Holes not used shall be filled. In partitions of light steel construction, sheet-metal screws may be used. Raceways shall not be supported from sheet-metal roof decks. In suspended-ceiling construction, raceways shall not be fastened to the suspended-ceiling supports.

4.6.4.2 Telephone and signal raceways.- Telephone and signal system raceways shall be installed in accordance with the previous requirements for conduit and tubing, with the additional requirements that no length of run shall exceed 50 feet for 1/2-inch and 3/4-inch sizes, and 100 feet for-1-inch or larger sizes; and shall not contain more than two 90-degree bends or the equivalent. Pull or junction boxes shall be installed to comply with these limitations, whether or not indicated on the drawings. Bends in conduit, 1 inch and larger, shall have minimum inside radii of 12 times the nominal conduit diameter.

4.6.5 Conductors

4.6.5.1 Uninsulated conductors.- Uninsulated conductors shall be copper and in accordance with Federal Specification QQ-W-343.

4.6.5.2 Insulated conductors.- Unless otherwise indicated, insulated conductors shall be copper with thermoplastic or thermosetting insulation, type THW, THWN, and XHHW for general use, or type THHN for use in dry locations only, all insulated for 600 volts in accordance with Federal Specification J-C-30. Unless otherwise indicated, conductors No. 10 AWG and smaller shall be solid. Conductors No. 8 AWG and larger shall be stranded. Minimum branch circuit conductor size shall be No. 12 AWG. Stranded conductors may be used with wire compression connectors or a pressure washer type lug; lugs with screw only compression are not allowed. Minimum control wire size shall be No. 14 AWG unless noted otherwise. Stranded conductors smaller than 10 AWG is allowed in applications where vibration and flexing may be encountered.

4.6.5.2.1 Fixture wiring.- Fixture wiring shall be thermoplastic insulated copper, rated for 600 volts, in accordance with Federal Specification J-C-30 and the NEC.

4.6.5.2.2. Color coding.- All feeder and branch circuits, including neutral conductors, shall be identified at both ends of the conductor with panel and circuit number indicated. This shall be accomplished using shrink embossed labels only. The color coding shall be continuous throughout the facility on each phase conductor to its point of utilization so that the conductor phase connection is readily identifiable. Equipment grounding conductors shall be color coded green. Conductors covered with green insulation with yellow, orange, violet or red tracers shall be used for other grounding systems. Neutral conductors shall be white insulated for 120/208/240 volt systems and gray insulated for 277/480 volt systems. For conductors, No. 4 AWG and larger, where appropriate insulation color is not available, color coded tape, half lapped for a minimum length of 3 inches shall be used. Switch leg conductors shall be violet insulated. Green, white, and gray insulated conductors shall not be reidentified. All conductor color codes including reidentified conductors shall be visible at all junction boxes, pullboxes, panelboards, outlets, switches, at access locations in closed raceways, every three (3) feet in open raceways, under all raised floors and at all terminations. Phase conductors shall be color coded as follows:

Single Phase

120 Volts	120/208/240 Volts
Line 1 - Black	Line 1 - Black Line 2 - Red
Neutral - White	Neutral - White

Three Phase

120/208/240 Volts	277/480 Volts
Phase A - Black	Phase A - Yellow
Phase B - Red	Phase B - Brown
Phase C - Blue	Phase C - Orange
Neutral - White	Neutral - Gray

Color coding for conductors in control cables shall be in accordance with NEMA Standard WC 5. DC power conductors. shall be color coded as follows: positive conductor, red with brown tracer; negative conductor, brown with red tracer; neutral conductors, if used, shall be white.

4.6.5.3 Splices.- Splices shall be made only at outlets , junction boxes or accessible raceways. Splicing of ungrounded conductors in panelboards is not permitted. Splices shall be made with solderless connectors conforming to UL 486A, UL 486C, AND UL 486E. Insulated wire nuts may only be used to splice conductors sized No. 10 AWG and smaller. Compression connectors shall be used to splice conductors No. 8 AWG and larger. All splices, including those made with insulated wire nuts, shall be insulated with electrical tape or shrink tubing to a level equal to that of the factory insulated conductors. All underground splicing shall be accomplished in accordance with FAA-C-1391.

NOTE:

Conductors in critical power systems shall not be spliced.

4.7 Boxes.- Boxes shall be either the cast-metal threaded-hub type conforming to UL 514A and UL514B, galvanized steel type conforming to UL 514A and UL 514B, or metal outlet boxes conforming to NEMA OS 1. All enclosures shall conform to NEMA standards.

4.7.1 Applications.- Boxes shall be provided in the wiring or raceway system for pulling wires, making connections, and mounting devices or fixtures. All outdoor boxes shall be rated minimum NEMA 3R. In hazardous areas, boxes shall be explosion proof. Each electrical outlet box shall have a machine screw which fits into a tapped hole in the box for the ground connection. Boxes shall be sized in accordance with the NEC Article 370. Boxes for mounting lighting fixtures shall not be less than 4 inches square. Boxes installed for concealed wiring shall be provided with extension rings or plaster covers. The front edge of the box shall be flush or recessed not more than 1/4-inch from the finished wall surface. Boxes for use in masonry-block or tile walls shall be square-cornered tile-type, or standard boxes having square-cornered tile-type covers. Cast-metal boxes installed in wet locations and boxes installed flush with exterior surfaces shall be gasketed. Separate boxes shall be provided for flush or recessed fixtures where required by the fixture terminal operating temperature, and fixtures shall be readily removable for access to the boxes unless ceiling access panels are provided. Boxes for fixtures on suspended ceilings shall be supported independently of the ceiling supports. Boxes shall not be supported from sheet-metal roof decks. Non-metallic boxes may be used only with non-metallic raceway systems.

4.7.2 Supports.- Boxes and supports shall be securely fastened to wood with wood screws, nails, screw-type nails, carriage bolts, or lag screws of equal holding strength, with bolts and expansion shields on concrete or brick, with toggle bolts on hollow masonry units, and with machine screws or welded studs on steel work. Support systems shall be capable of carrying the weight of the box and its contents. Threaded studs driven by powder charge and provided with lockwashers and nuts, or nail-type nylon anchors may be used in lieu of expansion shields, or machine screws. In open overhead spaces, cast-metal boxes threaded to raceways need not be separately supported except where used for fixture support; cast-metal boxes having threadless connectors and sheet-metal boxes shall be supported directly from the building structure or by bar hangers. Where bar hangers are used, the bar shall be attached to raceways on opposite sides of the box and the raceway shall be supported with an approved fastener not more than 24 inches from the box. Penetration shall be no more than 1-1/2 inches into reinforced concrete beams nor more than 3/4-inch into reinforced concrete joists. Main reinforcing steel shall not be cut.

4.8 Wiring devices

4.8.1 Receptacles.- All receptacles shall be specification grade in accordance with NEMA STD WD-1. Unless otherwise indicated, general purpose duplex receptacles shall be specification grade, 20 ampere rating, 125 volt, grounding type NEMA 5-20R. Receptacles with push-in connections or a combination of screw-type and push-in connectors are not acceptable. Unless noted otherwise, receptacles shall be installed 12 inches above finished floor. All receptacles, unless they are of the isolated-ground type, shall be grounded by the installation of a green grounding pigtail from the receptacle grounding screw directly to the grounding screw on the outlet box where the green equipment grounding conductor is terminated.

NOTE: For all critical power circuits, the receptacles shall be twist lock type except where the receptacles are not subject to be kicked or bumped (e.g., receptacles mounted inside an equipment rack).

4.8.1.1 General.

4.8.1.2 Ground fault circuit-interrupter (GFCI) receptacles.- GFCI receptacles shall be installed in all locations required by the NEC and in other locations as indicated on the drawings. GFCI receptacles shall be 125-volt, duplex, UL Group I, Class A, rated for 20 amperes minimum. All exterior GFCI receptacles shall be mounted in weatherproof boxes with weatherproof covers.

4.8.1.3 Reserved

4.8.1.4. Isolated ground terminal receptacles.- When isolated ground terminal receptacles are shown in the contract documents, they shall be installed in accordance with Article 250-74 exception #4, of the NEC. Isolated ground terminal receptacles shall only be used where shown on the drawings. All isolated ground terminal receptacles shall be colored orange.

4.8.1.5 Plug-in strip outlets

4.8.1.5.1 General.- Fixed multi-outlet assemblies shall consist of a surface metal raceway with grounding type receptacles. Phase and neutral conductors shall not be smaller than No. 12 AWG and shall have the type of insulation specified for branch circuit conductors. In addition, a No. 12 AWG or larger green insulated equipment grounding conductor having the same insulation as the phase conductors shall be installed. This grounding conductor shall connect all receptacle ground terminals and each section of the surface metal raceway, and shall be securely connected to the equipment grounding conductor from the branch power panel. Where more than one circuit is indicated as serving a group of similar receptacles in a common raceway, adjacent receptacles shall not be connected to the same circuit.

4.8.1.5.2 Associated hardware.- Surface metal raceways shall be provided with snap-on blank covers and/or snap-on receptacle covers for the receptacles furnished, all manufactured by the raceway manufacturer. They shall be installed to prevent open cracks. Where industry standard device plates are to be installed on raceways, snap-on blank covers shall be accurately cut to avoid open cracks. Fittings, elbows, clips, mounting straps, connection blocks, and insulators, shall be provided as required for a complete installation.

4.8.1.6 Emergency light receptacles.- Emergency light receptacles shall be grounding type single receptacles in accordance with NEMA standard WD 1.

4.8.2 Wall switches.- Single-pole and three-way wall switches shall be specification grade, rated 120/277 volts, and shall be fully rated 20 amperes, AC only. Wiring terminals shall be of the screw type. Switches with push-in connections or a combination of screw-type and push-in connections are not acceptable. Switches shall be equipped with grounding terminals and shall be grounded with a green grounding pigtail connected from the switch grounding screw directly to the grounding lug or screw on the outlet box where the green equipment grounding conductor is terminated. Switches shall be the quiet-operating type. Not more than one switch shall be installed in a single gang position.

4.8.3 Device plates.- Plates of the one-piece type shall be provided for all outlets and fittings to suit the devices installed. Plate screws shall be of metal with countersunk heads, in a color to match the finish of the plate. Telephone and communication outlets shall be provided with a blank cover plate unless otherwise indicated. Plates shall be installed with all four edges in continuous contact with finished wall surfaces with the use of mats or similar devices. Plaster fillings will not be permitted. Plates shall be installed with an alignment tolerance of 1/16 inch. The use of sectional type device plates will not be permitted. Plates installed in wet locations shall be gasketed. Device plates for telephone and intercommunication outlets shall have a 3/8-inch bushed opening in the center or a dome-shaped grommet on the side.

4.8.4 Photoelectric control.- Unless otherwise indicated, photoelectric controls for floodlighting or obstruction lighting shall be 120 volt, 3000 watt, single-pole, single-throw, double-break type. Photoelectric controls shall be mounted in an appropriate weatherproof housings installed on the building exterior. The housing should be vented if possible, faced in a northerly direction. At no time shall the controllers be mounted in the same enclosure with thre batteries.

4.9 Service equipment

4.9.1 Power.- Service entrance equipment and installation for power shall be in accordance with the regulations of the local utility providing service and NEC Article 230.

4.9.1.1 Service entrance conduits.- Service entrance conduits shall be installed as shown on the drawings and shall be heavywall zinc coated rigid steel unless otherwise indicated. Grounding bushings shall be installed on both ends of the service entrance conduit.

4.9.1.1.1 Underground service.- Underground service entrance conduits shall be installed a minimum of 2 feet below finished grade. Service entrance conduit shall be electrically continuous between the service disconnecting means and the facility transformer housing. The conduit shall be bonded to the counterpoise.

4.9.1.1.2 Aerial service.- A minimum of 4 feet of slack in all service entrance conductors shall be extended from an appropriate weatherproof entrance fitting to permit connection to the service drop. Conduit shall be concealed within the building where possible and conduit penetrations into the building shall be caulked with sealing compound.

4.9.1.2 Service disconnecting means.- Service equipment shall be a fused disconnect switch, separately mounted circuit breaker, or main circuit breaker in the main distribution panel. All switches and circuit breakers used as service entrance disconnecting means shall be UL rated for service equipment.

4.10 Panelboards

4.10.1 General.- Panelboards shall be dead-front type, shall conform to Federal Specification W-P-115, Type I, Class 1, and shall be listed by UL except for installations which require special panelboards to incorporate items not available as UL listed. Panelboards shall be mounted so that the height to the top of the panelboard shall not exceed 81 inches above the finished floor level. Unless otherwise specified, panelboards shall have a full hinged front cover with a hinged door in that cover for access to circuit breaker switches. Doors shall have flush type cylinder locks and catches. Doors over 48 inches in height shall have auxiliary fasteners on top and bottom. All locks in a project shall be keyed alike, and two keys shall be furnished with each lock. Directories shall be type written to indicate the load served by each circuit and shall be mounted on the inside of the door in a holder with a protective covering. Circuits shall be connected as indicated on the drawing. The directory shall be arranged so that the typed entries simulate circuit breaker positions in the panelboard.

4.10.2 Wiring gutters.- The minimum size of side wiring gutters shall be 4 inches for power feeders up to and including 100 amperes, 6 inches for power feeders over 100 amperes and up to 225 amperes, and 8 inches for power feeders over 225 amperes and up to 600 amperes.

4.10.3 Circuit breakers.- Circuit breaker ratings shall be in accordance with the SCA/PDC study, FAA Order 6950.27. All circuit breakers shall be UL listed thermal magnetic type or electronic solid state type, as described herein, and with a minimum rating of 10,000 AIC. Circuit breakers shall also have trip ratings, voltage ratings, and number of poles as defined on the drawings. All circuit breakers shall have a trip indicating feature. Single-pole breakers shall be full-size modules. Two-pole and three-pole breakers shall be physically sized in even multiples of a single-pole breaker. Breakers shall be sized so that two single-pole breakers can not fit in a single housing. Multipole circuit breakers shall have an internal common trip mechanism. All circuit breakers and the panelboards in which the breakers are installed shall be products of the same manufacturer. Plug in type load centers and/or plug in type branch or feeder circuit breakers shall not be used. Positive integral locking plug-in circuit breakers, and associated panelboards, may be used.

4.10.3.1 Thermal magnetic.- All thermal magnetic breakers shall be quick make, quick break type conforming to Federal specification W-C-375. Adjustable breakers shall have setting adjustments readily accessible and visible from the front of the panel board, after installation.

4.10.3.2 Solid state.- Adjustable, solid-state or microprocessor-controlled circuit breakers shall have adjustments readily accessible and visible from the front of the panelboard, after installation. Individual circuit breaker frame size shall not exceed the panelboard bus rating.

4.10.3.3 Self enclosed circuit breakers

4.10.3.3.1 General.- Circuit breakers shall be UL listed thermal magnetic type or electronic solid state type, as described herein. Multiple circuit breakers shall have an internal common trip mechanism. Circuit breakers shall comply with Federal Specification W-C-375.

4.10.3.3.2 Thermal magnetic.- These circuit breakers shall be of the molded-case type, shall have a quick-make and quick-break toggle mechanism, inverse-time trip characteristics and shall be trip-free on overload or short-circuit. Automatic release shall be secured by a BI-metallic thermal element releasing the mechanism latch. In addition, a magnetic armature shall be provided to trip the breaker instantaneously for short-circuit currents above the overload range.

Automatic tripping shall be indicated by a handle position between the manual OFF and ON positions.

4.10.3.3.3 Solid state/microprocessor.- These circuit breakers may be used providing they meet or exceed the performance characteristics given by paragraph 4.10.3.3.2 above.

4.10.4 Bus bars.- All phase bus bars shall be copper or plated copper. Neutral and ground bus bars shall be copper or plated copper. Bus capacity shall be as indicated on the drawings. Where bus capacity is not indicated on the drawings, the capacity shall be equal to or greater than the panelboard feeder overcurrent protective device. Except as indicated paragraph 4.10.3, circuit breaker current-carrying connections shall be bolted. Bus bar connections to branch circuit breakers shall be of the sequence phase type. The neutral bus shall be insulated from all panelboards except where the panelboard is used as the service disconnecting means. Where "provisions for," "future," or "space" is noted on the drawings, the panelboard shall be equipped with bus connections for the future installation of circuit breakers.

4.10.4.1 Ground bus.- All panelboards shall have an uninsulated ground bus that is separate from the neutral bus. The ground bus shall be securely bonded to the cabinet and adequately sized for the panelboard capacity and with the number of terminations equal to the number of poles in the panelboard. The ground bus shall only be bonded to the neutral bus at the service disconnecting means. The ground bus bar shall be structurally integral to the panelboard or attached to the panelboard with a bolt, nut and lock washer. If the ground bus bar is mounted to the enclosures with screw threads only (i.e., tapped blind hole) a separate, bolted ground lug shall be installed on the panelboard and bonded to the ground bus bar. The bond conductor shall have the same current carrying capacity as the largest equipment grounding conductor terminated to the ground bus bar.

4.11 Reserved.

4.12 Safety switches.- Safety switches shall be type "HD," heavy duty, locking type unless otherwise indicated. Switches mounted in dry locations shall be

NEMA type 1 enclosures. Switches installed outdoors, or in damp locations shall be mounted in NEMA type 3R enclosures. Switches shall be of the voltage and current ratings indicated on the drawings. Switches shall be the quick-make, quick-break type. Except for ground lugs which shall be bonded to the housing, all parts shall be mounted on insulating bases to permit replacement of any part from the front of the switch. All current-carrying parts shall be of high-conductivity copper unless otherwise specified. Switch contacts shall be silver-tungsten or plated to minimize corrosion, pitting and oxidation. When used for motors a safety switch shall be sized in accordance with NEC Article 380. Switches shall disconnect all ungrounded conductors.

4.13 Cabinets.- Telephone and signal systems cabinets shall be constructed of zinc coated sheet steel in accordance with NEC Article 373-10, and shall meet the requirements of UL 50. Cabinets shall be constructed with interior dimensions not less than those indicated on the drawings. Cabinets shall be mounted so that the height to the top of the cabinet does not exceed 81 inches above the finished floor level. A locking catch and two keys shall be provided with each cabinet unless otherwise indicated. All locks in a project shall be keyed alike. Cabinets shall also be provided with a 5/8-inch plywood backboard unless otherwise indicated.

4.14 Motors and controls

4.14.1 Motors.- Motors furnished under this specification shall be of sufficient size for the duty to be performed, and shall not exceed the full-load rating when the driven equipment is operating at specified capacity. Motors shall be rated for the voltage of the system to which they are to be connected. Unless otherwise indicated, all motors shall have open frames, and continuous-duty classifications. Polyphase motors shall conform to NEMA Standard MG-1, and shall be type II, class 3, minimum insulation class B, squirrel-cage type, having normal starting-torque and low-starting-current characteristics, unless otherwise specified. When motor horsepower ratings are indicated on electrical drawings, these ratings are only approximate. Higher ratings may be required to adequately power driven equipment selected by the contractor for the duty to be performed.

<u>4.14.2 Motor controls</u>.- Each motor, 1/8 horsepower or larger, shall have overload protection in each phase, or other equally rated method in accordance with the NEC. The overload-protection device shall be provided either integral with the motor, or with the control, or shall be mounted in a separate enclosure. In any case the reset button shall be in an accessible location. Unless otherwise indicated, the protective device shall be of the manual reset type. Single or double-pole tumbler switches specifically designed for AC operation may be used as manual controllers for single-phase motors having a current rating not in excess of 80 percent of the switch rating. Automatic control devices such as thermostats and float or pressure switches may control the starting and stopping of motors directly, provided the devices used are designed for that purpose and have an adequate horsepower rating. When the automatic control device operates the motor directly, a double-throw, three-position tumbler or rotary switch shall be provided for manual control.

<u>4.14.2.1 Reduced-voltage controllers</u>.- Reduced voltage starting methods when required shall be as indicated on the drawings.

<u>4.14.3 Motor disconnecting means</u>.- Each motor shall be provided with a disconnecting means and a manually operated switch as shown on the drawings or when required by the NEC. For single-phase motors, a single-pole or double-pole toggle switch, rated only for AC, will be acceptable for capacities less than 30 amperes, provided the ampere rating of the switch is at least 125 percent of the motor full load amperages (FLA). Enclosed safety switches shall conform with paragraph 4.12 above.

<u>4.15 Dry-type transformers</u>

<u>4.15.1 General</u>.- Dry-type transformers shall be of the sizes and characteristics shown on drawings. Unless otherwise indicated, the design, manufacture, and testing of dry-type transformers, and the methods of conducting tests and preparing reports shall be in accordance with NEMA ST 20, and UL standards. These transformers shall be dry-type self-cooled (Class AA) as defined by ANSI/IEEE C57.12.80. Unless otherwise indicated, minimum Basic Insulation Levels (BIL) shall be in accordance with IEEE STD 141.

4.15.2 Windings and taps.- Dry-type transformers shall be provided with separate primary and separate secondary windings for each phase. The transformers shall be provided with copper windings. Unless otherwise indicated, each primary winding of each transformer rated 15 KVA and greater shall be provided with four taps, two of which shall provide 2-1/2 percent increments above full rated voltage and two of which shall provide 2-1/2 percent increments below full rated voltage. Each primary winding of each transformer rated below 15 KVA shall, be provided with not less than two taps, each providing a 5 percent increment above and below full rated voltage.

4.15.3 Insulation.- Insulation provided in transformers having ratings not exceeding 25 KVA shall have 185°C rise rating. Insulation provided in transformers having ratings exceeding 25 KVA shall have 220°C rise rating.

4.15.4 Terminal compartments.- Each dry-type transformer shall be provided with a suitable terminal compartment to accommodate the required primary and secondary wiring connections, and side or bottom conduit entrance. Transformers having ratings not exceeding 25 KVA shall be provided with terminal leads equipped with factory installed and supported connectors. Transformers rated greater than 25 KVA shall have terminal boards equipped with factory installed clamp-type connectors. The terminal compartment temperature shall not exceed 75°C when the transformer is operating continuously at rated load with an ambient temperature of 40°C.

4.15.5 Sound pressure levels and vibration isolation.- Sound pressure levels of dry-type transformers shall be determined in accordance with NEMA Standard ST 20. Levels shall not exceed 40 db for transformers rated at 9 KVA or less; 45 db for transformers rated over 9 KVA but not over 50 KVA; and 50 db for transformers rated over 50 KVA but not over 150 KVA. All dry-type transformers 45 KVA and greater shall have integral vibration isolation supports between the core and coil assembly and the transformer enclosure. Transformers of lesser rating shall have either integral or external vibration isolation supports. Conduit connections to transformers shall be made with flexible metal conduit, nominally 12 inches length but not more than 36 inches in length.

4.15.6 Enclosures.- Single-phase transformers larger than 25 KVA and three-phase transformers larger than 15 KVA shall be fully encased in steel enclosures. Transformers smaller than 15 KVA shall be fully encased in steel enclosures with or without compound fill, or shall have exposed cores, impregnated windings, and steel enclosures encircling all live parts. Enclosures shall be bonded to the grounding system. The surface temperature of the transformer shall not exceed 65°C when the transformer is operating continuously at rated load with an ambient temperature of 40°C.

4.15.7 Mounting.- Transformers shall be mounted to allow for adequate ventilation. Unless otherwise indicated on drawings, dry-type transformers having ratings not exceeding 25 KVA shall be suitable for wall mounting. Shop drawings of wall brackets and platforms for transformers shall be submitted for approval.

4.16 Identification.- Motor controllers, panelboards, safety switches and self-enclosed circuit breakers shall be identified with a name plate showing the functional name of the unit, voltage utilized, the number of phases, and other pertinent formation. Switches for local lighting need not be identified. Additional equipment shall be identified if called for on the drawings.

4.16.1 Name plates.- Name plates shall be non-ferrous metal or rigid plastic, stamped, embossed or engraved with 3/8-inch minimum height characters. The plates shall be secured to the equipment with a weather-proof bonding material or a minimum of two screws.

4.17 Fuses.- A complete set of fuses shall be installed and one set of spares shall be furnished for each fusible device. Time and current tripping characteristics of fuses serving motors or connected in series with circuit breakers shall be determined by the facility Protective Device Coordination Study (PDC). Fuses shall have a voltage rating not less than the circuit voltage. Required fuse interrupting ratings, determined by the Short Circuit Analysis (SCA) calculations, shall be as shown on the drawings, except that these interrupting ratings shall not be less than 100,000 amperes in branch and feeder circuits, and not less than 200,000 amperes in a service entrance switch.

4.18 Lamps and lighting fixtures

4.18.1 General.- Lamps and lighting fixtures shall be of the types indicated on the drawings. All lighting fixtures shall be UL approved and shall bear the UL label. All incandescent lamps shall be rated for 130 volts unless otherwise indicated. Flexible metal conduit, minimum 3/8 inch nominal trade size is permitted. External bonding jumpers are not required across the lighting fixture flexible conduit.

4.18.2 Fluorescent fixtures.- Unless otherwise indicated, fluorescent fixture lenses shall be the prismatic-type, made of virgin acrylic. Fluorescent lamps shall be rapid start, cool white unless otherwise indicated. Ballasts for fluorescent fixtures shall be class P, protected (including inherent automatic thermal reset and fuse) rapid start, high power factor type, conforming to UL Standard UL 935. Unless otherwise indicated, all ballasts shall be provided with factory installed choke-type radio frequency interference suppressers. Lampholders shall have silver plated contacts, and shall conform to standard UL 542.

4.18.2.1 Recessed fluorescent fixtures.- Recessed fluorescent fixtures shall conform to NEC Article 410-64 through 410-72, and shall be installed in suspended ceiling openings. These fixtures shall have adjustable fittings to permit alignment with ceiling panels.

4.18.2.2 Suspended fluorescent fixtures.- Pendant-mount fluorescent fixtures shall conform to Federal Specification W-F-414 and shall be of the types indicated on the drawings. Single-unit suspended fluorescent fixtures shall have twin-stem hangers. Multiple-unit or continuous row fluorescent units shall have tubing or a stem for wiring at one point, and tubing or a stem suspension provided for each unit length of chassis, including one at each end.

4.18.3 Suspended incandescent fixtures.- Pendant-mounted incandescent fixtures shall be provided with swivel hangers to insure a plumb installation.

4.18.4 Emergency lights.- Emergency lights shall conform to Federal Specification W-L-305, type I, class I, style D or E, with the number of heads as indicated on the drawings. Emergency light sets shall be connected to the wiring system by a cord no more than 3 feet in length to a single receptacle.

4.18.5. High intensity discharge (HID) lamps.- HID lamps including mercury vapor, metal halide, and high or low pressure sodium shall be as indicated on the drawings. High power factor, constant wattage ballasts shall be furnished with HID lamps. Mercury vapor lamps shall be the color improved type.

4.19 Signal and communications

4.19.1 Entrance conduits.- Conduit materials shall be RSC unless otherwise indicated. Except where otherwise indicated, underground conduits shall be a minimum of 2 feet below finished grade and extend at least 5 feet beyond the grounding electrode system. The conduits shall be bonded to the grounding electrode system with No. 2 AWG bare copper conductor by exothermic welds or FAA-approved pressure connectors. Conduits installed for future use by others, such as for telephone, communications, electronic signals, etc., shall have both ends capped.

4.19.2 Transient protection demarcation box for electronic landlines.- A metallic, appropriately rated NEMA junction box, shall be installed where electronic landlines or conduits enter the facility. This box will house terminal boards, cables, and circuit transient protectors as shown on the contract drawings.

4.19.3 Fiber optics.- The use of fiber optics is recommended to replace metallic, control cables. Using fiber optics will eliminate outages and loss of service due to lightning strikes.

4.20 Painting and finishing.- Where factory finishes are not adequate to protect metal surfaces from corrosion, the contractor shall paint exposed surfaces prior to or after installation. All marred or damaged surfaces, except exposed metal for grounding purposes, shall be refinished to leave a smooth, uniform finish at final inspection.

4.21 Repair of existing work.- Electrical work shall be carefully planned. Where cutting, channeling, chasing, or drilling of floors, wall partitions, ceilings, or other surfaces is necessary for the proper installation, support, or anchorage of the conduit, raceways, or other electrical work, it shall be carefully done. The contractor shall repair, with equal material by skilled workers, any damage to facilities caused by the contractor's workers or equipment. Contracting Officer's prior approval must be obtained for the materials, workers, time of day or night, repair method, and for temporary or permanent repairs purposes. On completion, repair work shall be inspected and approved by the Contracting Officer with the concurrence of any other affected parties such as utility companies and airport authorities.

5. QUALITY ASSURANCE PROVISIONS

5.1 List of materials and equipment.- When required by the contract the contractor shall submit a list of materials and equipment to the Contracting Officer for approval.

5.1.1 Information required.- This list shall include manufacturer's style or catalog numbers. Partial lists submitted from time to time shall not be considered as fulfilling this requirement. Approval of materials will be based on manufacturer's published data. Approval of materials and equipment will be tentative, subject to submission of complete shop drawings, when required, indicating compliance with the contract documents.

5.1.2 Statement.- A manufacturer's statement indicating complete compliance with the applicable federal specification, military specification, or standards of ASTM, NEMA, or other commercial standard, is acceptable as indicating compliance with contract documents.

5.2 Shop drawings.- When required by the contract or by direction of the contracting officer, the contractor shall submit shop drawings for materials and equipment not completely identified by information submitted in the materials and equipment lists. This information shall include, but is not limited to panelboards, lighting fixtures, cable trays, switchgear, transformers, busways, cabinets, and lightning protection systems. In addition, the contractor shall provide the completed Short Circuit

Analysis/Protective Device (SCA/PDC) study, FAA Order 6950.27.

5.2.1 Coordination.- Drawings and submitted data shall be checked and coordinated with the work of other construction trades involved, before they are submitted for approval, and shall bear the contractor's stamp of approval as evidence of such checking and coordination.

5.2.2 Required data.- Drawings and submitted data shall be complete, assembled in sets and shall bear the date, drawing revision number, name of project or facility, name of contractor and subcontractor, and the clear identity of contents and location of work.

5.2.3 Approval.- The approval of drawings and submitted data shall not be construed as (1) permitting any departure from the contract requirements; (2) relieving the contractor of the responsibility for any errors, including details, dimensions, materials, etc.; or (3) approving departures from full size details furnished by the Contracting Officer.

5.2.4 Variations.- If drawings show variations from the contract requirements because of standard shop practice or for other reasons, the contractor shall describe such variations in a letter of transmittal to the Contracting Officer. If acceptable, the Contracting Officer may approve any or all such variations, subject to a proper adjustment in the contract. Contractors failing to describe such variations shall not be relieved of the responsibility for executing the work in accordance with the contract, even though such drawings have been approved.

5.2.5 Submission.- The contractor shall submit and obtain approval of shop drawings by the Contracting Officer before ordering materials or proceeding with any work associated with the shop drawings.

5.3 Tests

5.3.1 General.- Unless otherwise indicated, the contractor shall furnish all test instruments, materials and labor necessary to perform the following tests. All tests shall be performed in the presence of the Contracting Officer or his designated representative.

All instruments shall have been calibrated within a period of two years preceding testing. Calibrations shall be traceable to applicable industry recognized standards.

5.3.2 Cables.- All cables shall be tested in accordance with FAA Order 6950.22 prior to installation and again upon completion of the installation. All testing shall be accomplished before connection is made to any existing equipment.

5.3.3 Load balancing.- After the electrical installation has been completed, the contractor shall take current readings with a true RMS ammeter for the purpose of load balancing. These readings shall be taken at the service entrance, each feeder panelboard, each branch panelboard, and each separately derived source. The contractor shall redistribute single-phase loads where there is greater than a 20% difference between readings in any two phases. The contractor shall also be required to notify the Contracting Officer of current readings taken before and after installation, and any phase loaded above 80% of the rating of its overcurrent protective device.

5.3.4 Insulation resistance tests.- Feeder and branch circuit insulation tests shall be performed after installation, but before connection to fixtures or appliances. Motors shall be tested for grounds or short circuits after installation but before start-up. All conductors shall test free from short circuits and grounds, and have a minimum phase-to-phase and phase-to-ground insulation resistance of 30 megohms when measured with a 500-volt DC insulation resistance tester. Apply the test voltage for at least one minute after the meter reading has stabilized. The contractor shall submit a letter type test report to the Contracting Officer prior to final FAA inspection of the contractor's work. The report shall list the tests performed and results obtained.

5.3.5 Neutral isolation tests.- For all new installations, the neutral in the service entrance switch shall be tested for isolation from ground with an ohmmeter capable of reading greater than 20,000 ohms. This procedure to be used is detailed in the Appendix. This procedures can also be used to determine if there are any other neutral-ground connections on the load side of the service disconnecting means.

5.3.6 Earth resistance test.- To demonstrate compliance with paragraph 4.4.4, the contractor shall measure the resistance of the grounding electrode system. Tests shall not be conducted within 48 hours of a rainfall or in frozen soil. The contractor shall immediately notify the Contracting Officer if the specified resistance is not obtained. Upon project completion, the contractor shall also submit a written test report to the Contracting Officer, defining the test procedure and results obtained.

5.3.7 Operating test.- After the interior wiring system installation is completed, and at such time as the Contracting Offer may direct, the contractor shall conduct an operating test for approval. The equipment shall be demonstrated to operate in accordance with the requirements of this specification. The test shall be performed in the presence of the Contracting Officer or designated representative.

6. NOTES

6.1 General.- This specification is to be used as part of the contract documentation for construction and facility modification projects that do not require major design efforts. No waivers to contractors, other than those indicated as alternatives, are allowed. This specification is not to be used as a design guide. For design information, consult FAA-STD-019, Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities; FAA-STD-020, Transient Protection, Grounding, Bonding and Shielding Requirements for Equipment; FAA Order 6950.19, Practices and Procedures for Lightning Protection, Grounding, Bonding, and Shielding Implementation; FAA Order 6950.20, Fundamental Considerations for Lightning Protection, Grounding, Bonding and Shielding and other documentation as applicable.

6.2 Conflicts between documents.- In all but the smallest of modification or construction contracts, conflicts are unavoidable between the various documents cited in the contract or referenced in an included specification. Any proposal request using this document should contain the following provisions: "Prospective contractors shall, as part of their proposals, enumerate, identify, and list conflicts that exist with the contract documents, and between those documents and the rules, regulations, and codes of the local utility company and local, county or state governing bodies."

Appendix

FACILITY NEUTRAL/GROUND ISOLATION TESTING.

The following testing is to be utilized to verify required isolation between facility neutral and ground systems within the electrical distribution system and facility equipment. Neutral grounding at the service entrance disconnect means is still required by NFPA, NEC Article 250.

EQUIPMENT NEEDED: Volt-ohm meter, flash light, allen wrenches, screw drivers, socket wrenches, and wire markers.

NOTE 1: A resistance value of greater than 20,000 ohms is the minimum value for an acceptable neutral/ground isolation test. Any lesser value indicates an unacceptable isolation condition that must be investigated.

NOTE 2: Capacitors on the neutral line or capacitive effects of the distribution system will impact resistance readings. Always use the final, stabilized readings.

NOTE 3: High impedance meters are susceptible to acting as an antenna, picking up stray fields that would not be picked up by lower impedance meters. For this series of tests, it is highly recommended that low impedance meters be used, such as an analog meter the Simpson 260 or its equivalent, or use a digital meter the Fluke 8060a series or its equivalent.

STEPS:

1. Schedule a facility outage in order to conduct the tests.

2. Review one-line diagrams of the facility electrical distribution system.

3. Isolate and lock out all standby power sources.

4. Remove facility power by opening the service disconnect means.

CAUTION: Voltage is still present at the supply side (line side) of the service entrance disconnect.

5. Verify that no voltage is present at the load side of the service disconnect means with the voltmeter using progressively lower scales.

6. Open all circuit breakers in the facility distribution system.
7. Disconnect load side neutral conductor(s).

8. Measure resistance between disconnected load side neutral conductor(s) and the service entrance enclosure ground bus.

9. If resistance reading is acceptable, reconnect neutral conductor(s) and terminate testing.

10. If resistance reading is unacceptable, tag the grounded neutral conductor(s) and leave the conductor(s) disconnected.

11. Trace the tagged conductor(s) to the load and correct the unacceptable neutral/ground bond, or to the next downstream (towards the load) neutral termination.

12. At the next downstream location, remove each load side neutral conductor one at a time and measure resistance between the conductor and the enclosure. If the resistance reading is acceptable, re-terminate the conductor. If the resistance reading is unacceptable, tag the grounded neutral conductor and leave it disconnected. Measure resistance of the rest of the neutral bus immediately after identifying a grounded conductor, to possibly verify the rest of the bus as acceptable.

13. Continue downstream as described above until all unintentional neutral/ground bonds are found and corrected.

14. Reconnect all neutral conductor(s) except at the service entrance disconnect means. Measure resistance between the load side neutral conductor(s) and the service entrance enclosure to verify successful isolation of neutral/ground conductors.

15. Reconnect neutral conductor(s), close service entrance disconnect means.

16. Place standby power source on line.

APPENDIX 2

US DOT/FAA Specification FAA-STD-019c

Lightning Protection, Grounding, Bonding and Shielding

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FAA-STD-019c
June 1, 1999
SUPERSEDING
FAA-STD-019b, 8/28/1990

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

STANDARD

LIGHTNING PROTECTION, GROUNDING, BONDING AND

SHIELDING REQUIREMENTS FOR FACILITIES

FOREWORD

This document defines standard configuration and procedures for the application of lightning protection, surge and transient protection, grounding, bonding and shielding practices to the design and construction of facilities housing electronic equipment, and the installation of electronic equipment. This standard applies to new construction and modifications to existing facilities required for the installation of electronic equipment. Pertinent application of, or deviation from, this standard shall be recorded in contract documents and on the facility drawings and documentation.

Wide use of solid state components at FAA electronic facilities has resulted in a combining of several technologies contained in this standard. Solid state electronic equipment is highly susceptible to lightning induced transients, power line surges and voltage anomalies that occur most frequently because of improper grounding, bonding and shielding practices. The majority of the basic requirements and practices contained in this document have been developed from previous application to many different facility and electronic equipment types. Optimization of protection can be achieved during the design of new electronic equipment and facilities to house that equipment.

This standard contains 6 sections. Section 1 gives the scope and purpose of the standard. Section 2 lists reference documents. Section 3 gives the requirements for surge and transient protection, lightning protection, the earth electrode system, the electronic multipoint ground system, the electronic single point ground system, the National Electrical Code (NEC) compliance, bonding and shielding. Section 4 provides quality assurance requirements. Section 5 "Preparation for delivery", does not apply to this document. Section 6 contains notes and definitions.

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LIST OF FIGURES

LIST OF TABLES

1. SCOPE

1.1 Scope. This document defines standard configurations and procedures for new facilities and facility modifications in the application of lightning protection systems, surge and transient protection, grounding, bonding, and shielding. It provides requirements for the design, construction, modification or evaluation of facilities. It also provides reference information without imposing minimum or mandatory requirements for existing facilities.

1.2 Purpose. The requirements of this standard are intended to minimize electrical hazards to personnel and damage to facilities and electronic equipment from lightning and power faults, and to minimize electromagnetic interference levels.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The current issue of the following documents form a part of this standard and are applicable to the extent specified herein. If conflicts occur between these documents and the contents of this standard, the contents of this standard provide the superseding requirements.

Federal Specifications

P-D-680	Dry Cleaning Solvent

(Information required to obtain copies of federal specifications is available from General Services Administration offices in Atlanta, Auburn WA; Boston, Chicago, Denver, Fort Worth, Kansas City MO, Los Angeles, New Orleans, New York, San Francisco, and Washington DC)

FAA Specifications

FAA-C-1217	Electrical Work, Interior

FAA Standards

FAA-STD-012	Paint Systems for Equipment
FAA-STD-020	Transient Protection, Grounding, Bonding and Shielding Requirements for Electronic Equipment

FAA Orders

Order 6950.19	Practices and Procedures for Lightning Protection, Grounding, Bonding and Shielding Implementation
Order 6950.20	Fundamental Considerations of Lightning, Protection, Grounding, Bonding and Shielding

(Copies of these specifications, standards, orders and other applicable FAA documents may be obtained from the Contracting Officer issuing the invitation-for-bids or request-for-proposals. Requests should fully identify material desired, i.e. specification, standard, amendment, drawing numbers and dates. Requests should cite the invitation-for-bids, request-for-proposals, the contract involved, or other use to be made of the requested material.)

Military Documents

MIL-HDBK-237	Electromagnetic Compatibility/Interference Program Requirements
NACSIM 5203	Guidelines for Facility Design and Red/Black Installation (U) (Confidential Document)

(Single copies of Military specifications, standards, and handbooks may be requested by mail or telephone from the Naval Forms and Publications Center, 5801 Tabor Ave, Philadelphia PA 19120. Not more than five items may be ordered on a single request; the Invitation for Bid or Contract Number should be cited where applicable. Only latest revisions (complete with latest amendments) are available; slash sheets must be individually requested. Request all items by document number. For subscription service information, direct inquiries to the above address with additional marking (ATTN: CODE 56).

2.2 Non-Government documents. Refer to Para. 2.1, Government Documents.

National Fire Protection Association (NFPA)

NFPA 70	National Electrical Code (NEC)
NFPA 77	Static Electricity
NFPA 780	Lightning Protection Code

(Requests for copies of the National Electrical Code and the Lightning Protection Code should be addressed to the National Fire Protection Association, Batterymarch Park, Quincy MA 02269.)

Underwriters Laboratories, Inc.

UL 96	Lightning Protection Components
UL 96A	Installation Requirements for Lightning Protection Systems
UL 779	Electrically Conductive Floorings (ANSI-A148.1)

American National Standards Institute (ANSI)

IEEE Std C62.36-1994	IEEE Standard Test Methods for Surge Protectors Used in Low-Voltage Data, Communications, and Signaling Circuits
ANSI/IEEE C62.41-1991	IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits
ANSI/IEEE 1100-1992	IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment.
ANSI/ESD S7.1-1994	Floor Materials --Resistive Characterization of Materials

(Requests for copies of IEEE documents should be addressed to The Institute of Electrical and Electronic Engineers Inc., 345 East 47th Street, New York, NY 10017-2394, USA)

(Requests for copies of ESD documents should be addressed to The ESD Association Inc. 7902 Turin Road, Suite 4, Rome, NY 13440-2069, USA)

(Requests for copies of UL documents should be addressed to Underwriters Laboratories, 207 East Ohio St., Chicago IL 60611, ATTN: Publications.)

3. REQUIREMENTS

3.1 Surge and transient protection requirements

3.1.1 General. Lines, cables, and facility electronic equipment shall be protected against surges on AC power lines and transients on electronic land-lines from the effects of lightning. Ferrous conduit or guard wires shall be used to shield external lines and cables to minimize inductive coupling of transients from lightning discharges. Fiber optic lines and balanced metallic lines shall also be used when feasible. Transient suppression, similar to Figure 1, "Typical Configurations of Protection for Electronic Equipment from Conducted Landline Transients", shall be provided at the entrance of lines and cables to facility structures and electronic equipment enclosures as necessary to protect electronic equipment from conducted transients. A surge arrestor

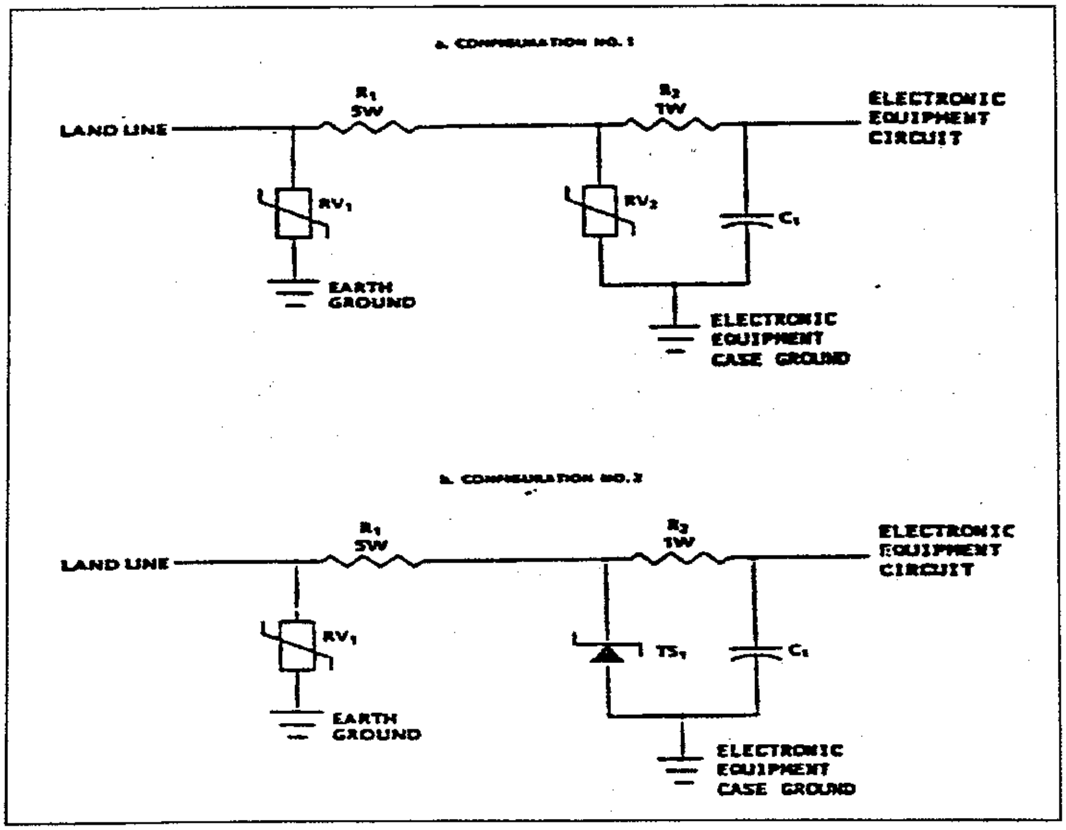


Figure 1 Typical Configurations of Protection for Electronic Equipment from Conducted Landline Transient

shall be installed at the AC service entrance to the facility. Implementation guidelines are contained in FAA Orders 6950.19 and 6950.20 and FAA-STD-020.

3.2 <u>External lines and cables</u>

3.2.1 <u>Fiber optic lines</u>. Fiber optic lines are not inherently susceptible to environmental interference or the induction fields produced by lightning. They are recommended to replace metallic lines when economically and technically feasible. Ferrous conduit shielding and suppression components are not required for fiber optic lines unless these lines use metallic or electrically conductive sheaths or strength members. Physical protection shall be provided for these lines.

3.2.2 <u>Balanced pair lines</u>. When possible, signals routed externally between facility shelters and buildings and to externally mounted electronic equipment shall be designed as balanced two conductor, shielded circuits. This does not apply to RF signals on coaxial lines.

3.2.3 Ferrous conduit. In this standard, ferrous conduit is defined as rigid galvanized steel conduit. Buried alternating current (AC) power lines and all buried electronic lines, conductors and cables to the facility shall be enclosed in watertight, ferrous conduit. However, where the length of the run exceeds 300 ft., the above lines, conductors and cables, except for the AC service conductors, into the facility may be armored cable as defined below. Conduit joints and fittings shall be electrically continuous with bonding resistance less than five milliohms between joined parts. Conduit enclosing AC power service entrance conductors shall be terminated using conductive fittings to the distribution transformer case and to the service entrance cabinet. Conduit enclosing signal, control, status, power, or other conductors to electronic equipment shall be terminated using conductive fittings to their respective junction boxes, equipment cabinets, enclosures, or other grounded metal structures. At each location where conduits first penetrates a shelter or building's exterior wall, direct connections shall be made to the electronic multipoint ground plate or to the earth electrode system as defined here after.

3.2.4 Buried guard wires. Buried lines, not completely enclosed in ferrous metal conduit, shall be protected by a bare No. 6 AWG, solid copper guard wire. The guard wire shall be embedded in the soil, a minimum of 10 in. directly above and parallel to the lines or cables being protected. The guard wire shall be bonded to the earth electrode system at each end and to ground rods at intervals not exceeding 300 feet using exothermic welds or FAA approved pressure connectors.

3.2.5 Armored cable. Armored cable shall be bonded to the earth electrode system at the point of entry into the facility with a No. 2 AWG bare copper conductor. Where this is not feasible, armor shall be bonded to the main ground plate. If none of the above are available, armor shall be grounded by bonding to the ground bus at the service disconnecting means. If armor is continued to the electronic equipment, it shall be bonded to the multipoint ground system of the electronic equipment unless the equipment is required to be isolated.

3.2.6 Facility entrance of buried cables. Buried cables shall enter a facility in ferrous conduit. The conduit shall extend a minimum of 5 ft. past the earth electrode system to prevent the introduction of surges and transients into the facility. The buried end of each of these conduits shall be bonded to the earth electrode system with a stranded bare copper conductor, No. 2 AWG, minimum. The other end of each of these conduits shall be bonded to their respective entrance housings.

3.3 Interior lines and cables. All cables and wiring exceeding 6 ft. in length shall be enclosed end-to-end in ferrous conduit, ductwork, cable trays or wireways that are connected to the electronic multipoint ground system as specified in Para. 3.11.5.1 and 3.11.5.2.

3.4 Location of surge and transient protection. The location of surge and transient protection for AC power lines and landlines is specified hereinafter and in FAA-STD-020.

3.5 Electronic equipment transient susceptibility levels. Electronic equipment supplied as part of the facility shall be provided with transient protection. The equipment susceptibility level is defined as the transient level on the line which may cause damage, degradation, or upset to electronic circuitry connected to the line. Protection for these levels is in addition to the levels specified in Para. 3.7 and shall meet requirements of FAA-STD-020.

3.6 Location of transient suppression equipment. When space is not available within equipment enclosures for the specified power line and landline transient suppression at entrances to equipment enclosures, transient suppression may be externally mounted to equipment enclosures using proper grounding, bonding and shielding procedures. See paragraphs 3.8.4 and 3.8.5 of this standard and FAA-STD-020 for guidance in terminating the ground conductor of suppression devices.

3.7 Conducted power line surges. To reduce transients conducted to electronic equipment, a surge arrester shall be provided at the service disconnecting means. Additional transient suppression components, devices or circuits shall be provided at power line entrances to electronic equipment as described in FAA-STD-020. Arrester protection devices at the service disconnecting means and transient suppression provided at electronic equipment power line entrances shall be functionally compatible.

3.7.1 Surge levels. Surge levels and number of occurrences for selection or design of facility AC arresters are given by Table I, Line-to-Ground Surge Levels for 120/208V and 277/480V AC Service Lines, and Table II, Line-to-Line Surge Levels for 480V AC Service Lines. Table I defines line-to-ground surge currents, and number of occurrences for 120/208V and 277/480V AC services. Table II defines line-to-line surge parameters for 480V AC services. In these tables the 8-by-20 ms wave form defines a transient with a rise time of 8 μs from inception to peak value that exponentially decays to 50 percent of peak value 20 μs after inception.

Table I LINE-TO-GROUND SURGE LEVELS FOR 120/208V AND 277/480V AC SERVICE LINES

Surge Current Amplitude 8-by-20 Microsecond Waveform	Number of Surges (Lifetime)	
	Normal Phase Current	
	100 A or Less	Greater than 100 A
10 KA	1,000	1,500
20 KA	500	700
30 KA	250	375
40 KA	25	50
50 KA	1	5
60 KA	-	2
70 KA	-	1

Table II LINE-TO-LINE SURGE LEVELS FOR 480V AC SERVICE LINES

Surge Current Amplitude 8-by-20 Microsecond Waveform	Number of Surges (Lifetime)
1 KA	1,000
10 KA	100
20 KA	50
30 KA	10

3.7.2 Facility AC surge arrester. A facility AC surge arrester shall be installed on the line side of the facility service disconnecting means. This surge arrester may be a combination of solid state circuits, varistors, or other devices and circuits designed to meet appropriate FAA specifications. These arresters shall be approved by the Contracting Officer. For services with a grounded neutral at the service disconnecting means, arrester elements connected line-to-neutral shall be provided. For services without a grounded neutral at the service disconnecting means, provide arrester elements connected line-to-ground and line-to-line. Lightning arresters shall also be installed on the primary side of FAA owned distribution transformers.

3.7.2.1 Characteristics. Minimum functional and operational characteristics of facility arresters for installation at service disconnecting means shall be as follows:

(a) Reverse standoff (maximum operating) voltage. Reverse standoff voltage is the maximum voltage that can be applied across arrester terminals with the arrester remaining in an off (non-conducting) state. Reverse standoff voltage of the arrester shall be 125±5 percent of normal line voltage.

(b) Leakage current. Leakage current shall not exceed 1 ma at reverse standoff voltage.

(c) Turnon voltage. Turnon voltage is the minimum voltage across arrester terminals that will cause the arrester to turn on and conduct. Turnon voltage shall not exceed 150 percent of reverse standoff voltage.

(d) Clamp (discharge) voltage. Maximum clamp voltage, when discharging the surges listed in Tables I or II, as applicable, shall not exceed electronic equipment damage voltage or operational upset voltage. Clamp voltage is the maximum voltage that appears across an arrester output terminal while conducting surge currents.

(e) Overshoot voltage. Overshoot voltage shall not exceed 2 times the arrester clamp voltage for more than 10 nanoseconds. Overshoot voltage is the surge voltage level that appears across the arrester terminals before the arrester turns on and clamps the surge to the specified voltage level.

(f) Self-restoring capability. The surge arrester shall automatically return to an off state after surge dissipation when line voltage returns to normal.

(g) Operating lifetime. The arrester shall safely dissipate the number and amplitude of surges listed in Tables I and II as applicable. Clamp (discharge) voltage shall not change more than 10 percent over the operating life of the arrester.

(h) Fusing. The input to each arrester device shall be internally fused to protect the AC power supply equipment against overload should an arrester device short. This fusing shall not increase the clamp voltage of the arrester and shall pass the surge current levels given by Tables I and II without opening. Fusing provided shall open on application of a steady state current at a level low enough to prevent damage or degradation to the AC power supply. Two indicator lamps per phase on the arrester enclosure cover shall visually indicate that a fuse has opened.

(i) In-line inductors. Use caution when selecting and installing in-line inductors, as they will increase the power source impedance. If the powered equipment has a significant current harmonic content requirement, unacceptable distortion of the voltage to that equipment may result from the installation of in-line inductors. Only inductors designed to have low DC resistance shall be used as in-line devices for AC arresters. In-line inductors shall safely pass electronic equipment operating voltages and line currents with 130 percent overvoltage conditions for a period of 50 milliseconds minimum. In conjunction with the arrester, inductors shall safely conduct the surge currents listed in Tables I and II. Service life of in-line inductors shall be a minimum of 10 years.

3.7.2.2 Packaging. All components comprising an arrester shall be packaged in a single National Electrical Manufacturers Association (NEMA) type 4 waterproof enclosure. Heavy duty, screw-type studs shall be provided for all input and output connections. The arrester elements shall be electrically isolated from the enclosure to a minimum of 10 megaohms resistance. The enclosure door shall be hinged and electrically bonded to the enclosure when shut. Hinges shall not be used to provide electrical bonding. Indicating lights shall be mounted on the front door. Fuses, lights, fuse wires and arrester elements or components shall be readily accessible for inspection and replacement.

3.7.2.3 In-line inductors. In-line inductor provided with or as part of secondary arresters may be installed within the arrester enclosure or in a separate enclosure on the electronic equipment side of the arrester elements.

3.7.2.4 Installation. The arrester shall be installed as close as practical (within 12 in.) to the facility service disconnecting means. Wiring connections shall be on the line side of the service disconnecting means and may be larger than the gage specified herein if recommended by the arrester manufacturer. Connections shall be pressure type, UL approved for the application.

(a) Phase connections. Phase lugs of the surge arrester shall be connected to corresponding phase terminals of the service disconnecting means with insulated No. 4 AWG (minimum) stranded copper cable. Connections shall be as short and direct as possible without loops, sharp bends or kinks.

(b) Ground connections. The ground connection for the surge arrester elements shall be routed as directly as possible, with no loops, sharp bends or kinks, to the earth electrode system. However, when the grounding electrode conductor in the service disconnecting means is properly connected to the neutral conductor bus and is routed as described above, the ground for the arrester elements may be connected to the neutral bus in the service disconnecting means. This connection shall also be as short as possible with no loops, sharp bends or kinks. The ground conductor for the arrester elements shall be No. 4 AWG (minimum) stranded copper cable color coded white when connected from the arrester to the service disconnecting means.

(c) Equipment grounding conductor. The surge arrester enclosure shall be connected to the ground bus in the service disconnecting means enclosure with No. 6 AWG copper wire. The wire shall have green insulation.

3.7.3 Electronic equipment power lines. Transient suppression devices, components or circuits for protection of electronic equipment power lines shall be provided as an integral part of all electronic equipment. These devices shall be positioned at the AC power conductor entrance to electronic equipment provided as part of the facility. Transient suppression shall be provided for both neutral and phase conductors. A detail design effort shall be completed in conjunction with the selection of the arrester at the service disconnecting means and the electronic equipment requirements described in FAA-STD-020. The design and selection of these transient suppressors shall be approved by the Contracting Officer.

3.8 Conducted landline transients. Transient protection shall be provided for all landlines both at facility entrances and at entrances to electronic equipment. Landlines include all signal, control, status and interfacility electronic equipment power lines installed above and below grade between facility structures and to externally mounted electronic equipment. All unused conductors of a cable shall be grounded at each end. This shall be accomplished by connection to the grounded shield at the terminal strip. Additional design and packaging requirements applicable to audio, radio frequency (RF) and other signals transmitted by axial cables are specified in Para. 3.8.7. Transient protection shall be provided for all landlines including landlines provided or installed by the telephone company.

3.8.1 Transient levels. Electronic equipment using landlines shall be protected against the transient levels defined in Table III, Conducted Landline Transient Levels. Transient levels for landlines installed in ferrous conduit are different from those for landlines not in ferrous conduit. Landlines in ferrous conduit require transient protection only at electronic equipment entrances. Landlines not in ferrous conduit require protection both at electronic equipment and facility entrances. The 8-by-1000 ms waveform in Table III defines a transient with an 8 ms rise time and a decay to 50 percent of the peak voltage in 1000 ms.

Table III CONDUCTED LANDLINE TRANSIENT LEVELS

No. of Transients (8-by-1000) Microsecond Waveform	Peak Amplitude (Voltage and Current)	
	Lines In Ferrous Conduit	Lines Not In Ferrous Conduit
1,000	50V, 10A	100V, 50A
500	75V, 20A	500V, 100A
50	100V, 25A	750V, 200A
5	100V, 50A	1000V, 1000A

3.8.2 Protection design. Detailed analyses of suppression component and electronic equipment circuit characteristics are required to select components compatible with the requirements of Para. 3.5 and to provide suppression circuits that will function without adversely affecting signals and information transmitted by individual landlines. Typical configurations for protection of electronic equipment from conducted landline transients are illustrated in Figure 1. Design requirements for selection of components are as follows:

(a) Unipolar suppression components shall be selected and installed for signals and voltages that are always positive or always negative relative to reference ground. Bipolar suppression components shall be selected for signals and voltages that are both positive and negative relative to reference ground.

(b) The total series resistance of the suppression circuits at both ends of a landline shall not degrade electronic equipment performance.

(c) The high energy protection components at facility entrances (varistor in Figure 1) shall be selected to reduce the magnitude of transient levels to equipment, clamping or limiting transient parameters safely below electronic equipment susceptibility levels for individual lines.

(d) The resistor, R1, shall limit the transient current conducted by the suppression component at electronic equipment entrances. The resistor, R1, shall ensure that the transient voltage at the facility entrance will turn on the facility entrance suppressor before the rated current level of the electronic equipment entrance suppressor is exceeded. The suppression components at the facility and electronic equipment entrances, and R1, shall be selected to function together.

(e) The electronic equipment entrance low energy suppressor shall be selected to clamp and limit the transient voltage and energy safely below electronic equipment circuit susceptibility levels.

(f) When the lowest voltage device available, such as silicon avalanche suppressors, will not adequately limit the transient voltage to electronic equipment circuits, a properly sized resistor, R2, shall be used to further reduce transient voltages.

(g) Capacitor C1 shall be selected in conjunction with R2 to attenuate high frequency transient energy.

3.8.3 Functional requirements. The combined operating characteristics for landline transient suppression at facility and electronic equipment entrances and requirements for individual devices shall be as follows:

(a) Reverse standoff voltage. The operating or reverse standoff voltage rating of the suppression components shall not exceed 20 + 5 percent above normal line voltage.

(b) Turnon voltage. Turnon voltage of the suppression components shall be as close to reverse standoff voltage as possible using state-of-the-art devices, and shall not exceed 125 percent of reverse standoff voltage.

(c) Overshoot voltage. Overshoot voltage amplitude and duration limits shall be low enough to preclude electronic equipment damage or operational upset. The requirement shall apply for transients with rise times up to 5,000 V/ms.

(d) Clamp (discharge) voltage. Clamp voltage shall be below the electronic equipment susceptibility levels while dissipating the transients listed in Table III.

(e) Operating life. The transient suppression system shall dissipate the transients defined in Table III. Clamp voltage levels shall not change more than 10 percent over the operating life of the suppression system.

(f) Self-restoring capability. The transient suppression system shall automatically return to the off state when the transient voltage level drops below turnon voltage for the suppressors.

3.8.4 Installation at facility entrance. High energy transient suppression components for electronic equipment , signal, and control lines (sometimes refereed to as the A Bus) shall be housed in shielded compartmentalized metal enclosures at the point where the landlines enter the facility. A ground bus bar, electrically isolated from the enclosure, shall be provided in the junction box to serve as an earth ground point for the high energy transient suppressors. The ground bus bar shall be directly connected to the earth electrode system with an insulated No. 4 AWG stranded copper wire of minimum length with no loops, sharp bends or kinks. The wire insulation shall be 600 volts color coded green with a bright red tracer. The ground bus bar location shall permit a short, direct connection to transient suppressors. The installation shall provide easy access to component terminals for visual inspection and test. Each suppression device shall be replaceable, or as a minimum, the suppressor and resistor for each line shall be replaceable as a unit.

3.8.5 Installation at electronic equipment. Low energy transient suppression components for electronic equipment (sometimes known as the A Bus) may be housed along with the high energy transient suppression components described in Para. 3.8.4, or in a separate enclosure mounted to the electronic equipment rack or shielded as an integral part of electronic equipment design as defined in FAA-STD-020. Suppression component grounds shall be connected directly to the metal enclosure and then to the electronic equipment case (part of electronic multipoint ground system) with an insulated 600 VAC No. 6 AWG stranded copper conductor color coded green with a bright orange tracer. Access shall be provided for visual inspection and replacement of components.

3.8.6 Externally mounted electronic equipment. When landlines terminate directly to externally mounted electronic equipment, landline transient protection as described in paragraphs 3.8.4 and 3.8.5 for facility and electronic equipment entrances shall be combined and provided at the electronic equipment line entrance.

3.8.7 Axial lines. Transient protection for electronic equipment using coaxial, tri-axial and twin-axial landlines not protected by ferrous conduit shall be provided both at facility entrances and at the electronic equipment. Lines protected externally by ferrous conduit require protection only at electronic equipment entrances. Transient suppression shall be provided equally for each conductor and shield that is not grounded directly to the electronic equipment case. The protection provided for electronic equipment using axial landlines shall comply with the requirements given in Para. 3.8 through 3.8.6 and the following:

3.8.7.1 Protection design. Special attention shall be given to the design of transient protection for axial-type lines. Design may be particularly critical at RF frequencies. The following design requirements apply.

(a) Suppression circuits shall be designed using components which have minimum effect upon the signals being transmitted.

(b) Suppression equipment layouts, circuit designs and enclosures shall be designed to minimize the effect on transmitted signals. Feedthrough components, leadless components, or short direct lead connections without bends improve performance of suppression circuits and reduce signal degradation.

(c) Analyses and tests shall be performed when necessary to assure that suppression components do not unacceptably degrade signals or cause marginal electronic equipment operation. Particular attention shall be given to impedance, insertion loss and voltage standing wave ratio for RF signals.

(d) When transient protection as specified herein cannot be provided for specific lines without unacceptable degradation of performance, alternative designs shall be submitted in writing for Contracting Officer approval.

3.8.7.2 Metal bulkhead connector plates. A metal bulkhead connector plate shall be provided where axial-type lines first enter a facility. The connector plate shall be a minimum of 1/4 in. thick and shall be constructed of tinned copper or other material compatible with the connectors. When more than one is needed, the plate or plates shall have the required number and types of feed-through connectors to terminate the external lines. The connectors shall provide a path to ground for cable shields except when the shield must be isolated for proper equipment operation. If external and internal cables are of a different physical size, the changeover in connector size may be accomplished by the feed-through connectors at the plate. The bulkhead connector plate shall be bonded to the earth electrode system with a No. 2/0 AWG insulated copper cable, color coded green with a red tracer. Additionally, where building steel is properly bonded to the earth electrode system, the bulkhead connector plate shall be connected to building steel. Exothermic welds or FAA approved pressure connectors (covered in paragraphs 3.14 through 3.14.14.4) shall be used for these connections.

3.8.7.3 Installation at facility entrances. Transient suppression components for axial-type lines shall be installed in a sealed metal enclosure with appropriate connectors at each end to permit in-line installation at the bulkhead connector plate. The ground connection for varistors or other suppression devices used at facility entrances shall be isolated from the suppression circuit enclosure. An insulated ground lead shall be brought out of each suppression circuit enclosure and connected to an adjacent ground bus or tie point. The ground bus shall be isolated from the connector plate and connected directly to the facility earth electrode system with a dedicated No. 4 AWG insulated stranded copper conductor, colored green with a bright red tracer. (This ground conductor shall be separate from the conductor noted in Para. 3.8.7.2.) All ground leads and wire shall be as short as possible with no loops, sharp bends or kinks. Bonding to this isolated ground bus shall be by UL approved connectors. Exothermic welds or FAA approved pressure connectors shall be used for connections to the earth electrode system.

3.9 Lightning protection system requirements

3.9.1 General. The intended purpose of the lightning protection system is to provide preferred paths for lightning discharges to enter or leave the earth without causing facility damage or injury to personnel. The essential components of a lightning protection system are air terminals, roof and down conductors connecting to the earth electrode system, and the earth electrode system. These components act together as a system to dissipate lightning currents. The lightning protection system shall meet the requirements of the Lightning Protection Code, National Fire Protection Association (NFPA 780) and the Installation Requirements for Lightning Protection Systems, Underwriters' Laboratories (UL 96A) and as specified herein.

3.9.2 Materials. All equipment used shall be UL approved and marked in accordance with UL procedures. All equipment shall be new and of a design and construction to suit the application in accordance with UL 96A requirements, except that aluminum shall only be used on aluminum roofs, aluminum siding or other aluminum surfaces. Bronze and stainless steel may be used for some components. Aluminum materials shall not be used on surfaces coated with alkaline-base paint, on or embedded in masonry or cement, on copper roofing, in contact with copper materials, or underground. Bimetallic connectors shall be used for interconnecting copper and aluminum conductors. Dissimilar materials shall conform to the bonding requirements of Para. 3.14.12.

3.9.3 Main conductors. Roof and down conductors shall be stranded and shall meet the requirements given in NFPA 780. Down conductors shall be routed outside of any structure and shall not penetrate or invade that structure except as indicated in Para. 3.9.11, Antenna towers.

3.9.4 Hardware. Hardware shall meet the following requirements.

3.9.4.1 Fasteners. Roof and down conductors shall be fastened at intervals not exceeding 3 ft. (0.9 m). Fasteners shall be of the same material as the conductor base material or bracket being fastened, or other equally corrosion resistant material. Galvanized or plated materials shall not be used. See Para. 3.14.13 for preparation of bonding surfaces.

3.9.4.2 Fittings. Bonding devices, cable splicers, and miscellaneous connectors shall be suitable for use with the installed conductor and shall be copper, bronze or aluminum with bolt pressure connections to the cable. Cast or stamped crimp type fittings shall not be used.

3.9.5 Guards. Guards shall be provided for down conductors located in or next to driveways, walkways or other areas where they may be displaced or damaged. Guards shall extend at least 6 ft. (1.8 m) above and 1 ft. (0.3 m) below grade level. Guards shall be metal or schedule 40 polyvinyl chloride (PVC) pipe.

Metal guards shall be bonded to the down conductor at both ends. Bonding jumpers shall be of the same size as the down conductor. PVC guards do not require bonding. Crimp type fittings shall not be used.

3.9.6 Bonds. Certain metallic bodies located outside or inside a structure contribute to lightning hazards because they are grounded or assist in providing a path to ground for lightning currents. Such metallic bodies shall be bonded to the lightning protection system wherever it is likely for a side flash to occur between the lightning protection system conductors and a grounded metal body. This shall be done in accordance with NFPA 780. Bonding should also be applied to other metal bodies, permanently affixed to the structure, because of their size or relative position to the lightning protection system conductor.

3.9.6.1 Metallic bodies subject to direct lightning discharge. Metallic bodies, on roofs, subject to direct lightning discharge are generally any large metallic body whose size causes it to protrude beyond the zone of protection of the installed air terminals. This includes exhaust fans, metal cooling towers, HVAC units, ladders, railings, antennas, and large louvered structures. When these metallic bodies have a metal thickness of 3/16 in. or greater, they shall be bonded to the nearest main lightning protection system conductor with UL approved fittings and conductors meeting the requirements of NFPA 780. These bonding fittings shall provide surfaces of not less than 3 square inches. Provisions shall be made to prevent corrosive effects introduced by galvanic action of dissimilar metals at bonding points. If the metal parts of these units are less than 3/16 in. thick, additional approved air terminals, conductors and fittings, providing a two way path to ground from the air terminals, shall be installed.

3.9.6.2 Metallic bodies subject to induced charges. Metallic bodies, on or below roof level, that are subject to induced charges from lightning include roof drains, plumbing vents, metal coping, metal flashing, gutters, downspouts, small metal wall vents, door and window frames, metal balcony railings, and in general any isolated metallic body within 6 ft. of an exposed lightning protection system element. These metallic bodies shall be bonded to the lightning protection system using UL approved splicers, fittings and conductors. Conductors used for bonding these metallic bodies shall be Class I secondary conductors in accordance with NFPA 780.

3.9.7 Conductor and conduit routing. Roof and down conductors shall maintain a horizontal or downward course. No bend in a roof or down conductor shall form an included angle of less than 90 degrees, nor shall it have a bend radius of less than 8 in. (203 mm). Conductors shall be routed external to buildings and 6 ft. (1.8 m) or more from power or signal conductors.

3.9.8 Down conductor terminations. Down conductors used to ground air terminals and roof conductors, shall terminate on buried ground rods, 1 ft. (0.3 m) to 2 ft. (0.6 m) vertically below ground level and from 2 ft. (0.6 m) to 6 ft. (1.8 m) outside the foundation or exterior footing of the building. Down conductors shall be connected to the ground rods by exothermic welding.

3.9.9 Disconnects. All down conductors except one may be provided with a screw type connector as described in UL 96 where lightning protection system testing may be required.

3.9.10 Buildings. Lightning protection shall be provided for all buildings, or parts thereof, not within a zone of protection provided by another building or higher part of a building, or by an antenna or tower. Zones of protection for all structures shall be as defined in NFPA 780.

3.9.10.1 Air terminals. Air terminals shall be solid copper, bronze or aluminum. Copper air terminals may be nickel plated. Air terminals shall be a minimum of 12 in. (305 mm) in height, at least 1/2 in. (12.7 mm) in diameter for copper and 5/8 in. (15.9 mm) in diameter for aluminum, and shall have a rounded or "bullet" point. Air terminals shall be located in accordance with the requirements of NFPA 780 and UL 96A. Air terminals shall extend at least 10 in. above the object or area it is to protect. Air terminals shall be placed on the ridges of pitched roofs and around the perimeter of flat or gently sloping roofs at intervals not exceeding 20 ft. (6 m) except that air terminals 24 in. (600 mm) or higher may be placed at intervals not exceeding 25 ft. (7.6 m).

> SAFETY NOTE: Where a personnel injury risk exists, should a person fall and strike an air terminal, the tip of the air terminal shall not be less than 5 ft. above the walking or working surface.

3.9.10.2 Number of down conductors. Not less than two down conductors shall be provided for buildings with perimeters of 250 ft. (76 m) or less. Down conductors shall be as widely separated as possible, i.e. at diagonally opposite corners on square or rectangular buildings. Buildings with perimeters in excess of 250 ft. (76 m) shall have one down conductor for each 100 ft. (30.5 m) of perimeter distance or part thereof.

3.9.10.3 Metal parts of buildings. Metal roofing, siding, eave troughs, down spouts, ladders, ducts and similar metal parts shall not be used as substitutes for roof or down conductors. A lightning conductor system shall be applied to the metal roof and to the metal siding of a metal clad building in the same manner as on a building without metal covering. Building metal parts shall be bonded in accordance with Para. 3.9.6.

3.9.10.4 Roof mounted antennas. If metallic, the mast of a roof mounted antenna shall be bonded to the nearest roof or down conductor using UL approved fittings and conductors. The bonding jumper shall be of the same size and material as the roof or down conductor to which it is connected.

3.9.11 Antenna towers. Antenna towers shall be provided with lightning protection in accordance with the following:

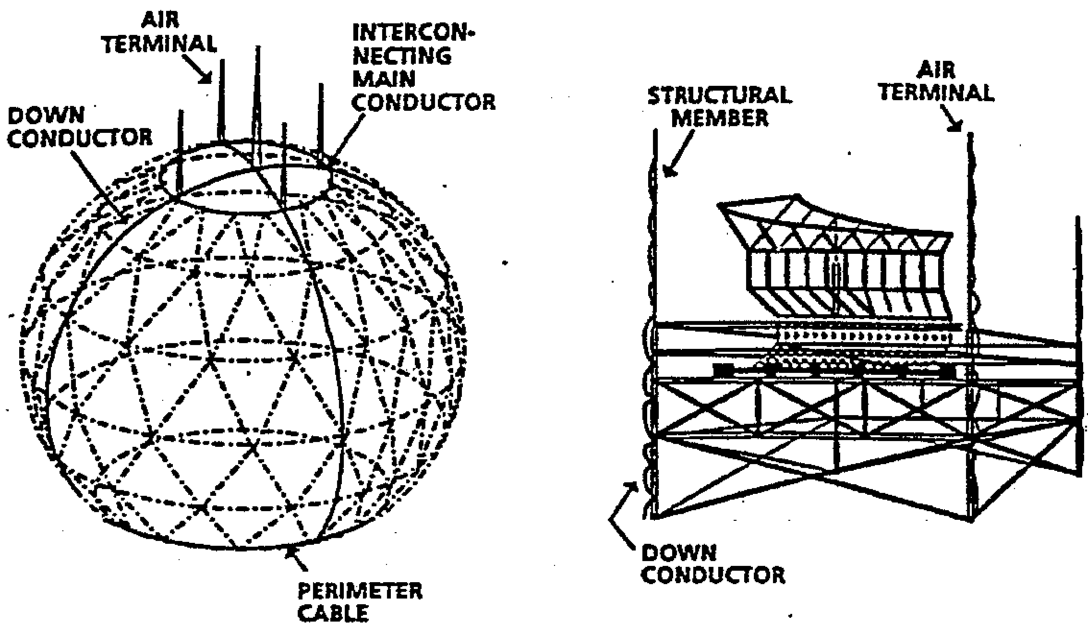
3.9.11.1 Number of down conductors. Pole type towers shall have one down conductor. Towers which consist of multiple, parallel segments or legs which sit on a single pad or footing not over nine square feet in area are considered pole type towers. All other towers shall have at lease two down conductors. Down conductors for all tower types shall be bonded to each tower section. Down conductors shall be routed down the inside of the legs wherever practical and secured at intervals not exceeding 3 ft. (0.9 m) in accordance with Para. 3.9.4.1.

3.9.11.2 Towers without radomes. Towers without radomes shall be protected by one or more air terminals to provide a zone of protection for all antennas located on the tower in accordance with NFPA 780. Protection may be provided for large RADAR antennas by extending structural members above the antenna and mounting the air terminal on top as shown in Figure 2, Lightning Protection for Radomes and Radar Antenna Platforms. Structural members shall be braced as required and shall not be used as part of the air terminal. The air terminal shall be supported on the structural member and shall have an UL approved fitting on its base. The air terminal shall be connected to a conductor installed around the perimeter of the tower platform. Down conductors as defined in Para. 3.9.11.1 shall be run from the perimeter cable to the earth electrode system. Except where only one down conductor is required, each air terminal shall be provided with at least two paths to ground. All conductors shall be UL approved and in accordance with NFPA 780 for main conductors.

3.9.11.3 Towers with radomes 25 ft. in diameter or less. Towers with spheroidal radomes 25 ft. (7.6 m) and less in diameter shall be protected with a single 2 ft. (0.62 m) air terminal at the radome peak. Two down conductors shall be routed, following the contour of the radome, from the air terminal to a peripheral conductor that forms a closed loop around the base of the radome. Framing having a zigzag pattern shall not be used because the path thus established is not suitable for lightning protection. Two down conductors shall be installed down opposite tower legs to the earth electrode system from the peripheral conductor in accordance with Para. 3.9.11.1.

3.9.11.4 Towers with radomes greater than 25 ft. in diameter. Towers with spheroidal radomes greater than 25 ft. (7.6 m) in diameter shall be protected with a 2 ft. (0.62 m) air terminal at the peak and four air terminals equally spaced around the circumference of the radome. Spacing of the four circumferential air terminals may be adjusted if the antenna pattern is affected, but their position and height shall establish a protection zone as defined by NFPA 780. Metal framed radomes, if electrically continuous throughout, may be used instead of the four lower mounted air terminals. The electrically continuous path of the radome when substituted for the four air terminals must provide a straight line path. Framing having a zigzag pattern shall not be used because the path thus established is not suitable for lightning protection. The four additional air terminals shall be interconnected with a main size conductor. This conductor shall be connected to the air terminal on the peak with two down conductors and to the perimeter cable that forms a loop around the base of the radome with two down conductors. The down conductors noted above shall be run in a straight downward path following the contour of the radome as shown in Figure 2. The perimeter cable shall be connected to the earth electrode system with a minimum of two down conductors in accordance with Para. 3.9.11.1. All conductors shall be UL approved for lightning protection systems and sized in accordance with the requirements of NFPA 780.

Conductors in the radome (down conductors and perimeter) shall be supported with approved fittings at intervals not exceeding 3 ft. (0.9 m).



NOTES:

1. **On a metal platform, four (4) platform mounted air terminals may be used.**
2. **Where a radome has an electrically continuous frame, the framing may be used in lieu of the lower four (4) air terminals shown.**
3. **Regardless of the protection configuration used, a minimum of two (2) down conductors shall be used to connect the air terminals to earth ground.**

Figure 2 Lightning Protection for Radomes and RADAR Antenna Platforms

3.9.11.5 Antenna protection. Air terminals shall be placed to protect structural towers and buildings, and antennas mounted to towers and on buildings.

3.9.12 Fences

3.9.12.1 Fences and gates. Fences made of conducting material, i.e. chain link fabric, metal crossbar, stranded wire, shall be constructed using metal posts which extend a minimum of 2 ft. (0.6 m) below grade. Gates shall have a 1 in. by 1/8 in. flexible tinned copper bond strap to the adjacent post. The posts at each side of the gate shall also be bonded together with a 2/0 AWG bare stranded copper cable. Bonds to these posts shall be 6 in. above grade. Metallic fence fabric with non-conductive coatings shall not be used.

3.9.12.2 Overhead power line considerations. When a fence constructed of conducting material is crossed by overhead power lines, the fence shall be bonded with bare No. 6 AWG copper conductors a minimum of 20 ft. to each side of the crossing. For a chain link fence, the fabric shall be bonded at each side to this conductor at the top, middle and bottom and at each strand of security wire placed above the fencing fabric. Where cross bar or stranded wire is used, each horizontal strand or cross bar shall be bonded top-to-bottom to the conductor.

3.9.13 Airport Traffic Control Towers (ATCT). ATCTs having electronic areas in the cab, junction and sub-junction levels at the top of the shaft and also in the associated base building present a unique set of challenges for implementing lightning and transient protection. The numerous conductors running between electronic equipment located in the base building and beneath the tower cab are subject to large electromagnetic fields during a lightning strike. For this reason special techniques must be applied to provide an environment that minimizes the damaging effects of lightning. These techniques are mandatory for ATCT facilities over 100' in height with base buildings, in isokeraunic areas of 30 thunderstorm days annually or greater, designed after the effective date of this change.

3.9.13.1 General. The electrical, electromechanical, electronic systems, and building steel of structures must be bonded together for safety. The National Electrical Code (NEC) NFPA-70 as well as this and other FAA Standards and Orders mandate this bonding. It is not possible for equipment near the top of the tower and that at the base to have the same potential during a lightning strike. It is therefore necessary to reference all systems at the top of the tower to each other and treat this area as a separate facility.

3.9.13.2 Main Ground Plate and Power Distribution. In order to assure good high frequency grounding during normal operation a low impedance connection must be provided to the Earth Electrode System (EES). A main ground plate shall be established on the lowest junction level beneath the cab with electrical, electromechanical, or electronic equipment. All grounding systems present at or above this level within the ATCT shall be connected to this main ground plate. A 1-foot wide #26 gauge or thicker copper strap shall connect this main ground plate to a plate at the base of the ATCT. This base plate shall be grounded via 2 ea. 500MCM cables exothermically welded to the base plate and to the EES. This strap will provide 2 ft^2 of surface per lineal foot of conductor and shall be routed continuously from the main ground plate to the base plate without sharp bends, loops, kinks, or splices. A combination of smaller conductors providing the same surface area per lineal foot may be substituted. This conductor shall be mechanically bonded to the main ground plate and the base plate. The strap should be sandwiched between the plate at each end and a 1'x1"x1/8" copper backing to insure good mechanical contact. The connection from the base plate to the EES shall be accomplished in an access well to facilitate periodic inspection All power distribution for the areas at the top of the ATCT shall be via separately derived source(s). These separately derived source(s) shall be grounded in accordance with the requirements of NEC article 250-26. The Grounding Electrode Conductor (GEC) specified in NEC article 250-26 (b) shall be connected to the grounded and grounding conductors at the first system disconnecting means or overcurrent device. This point of connection is mandated to facilitate the effective installation of a Transient Voltage Surge Suppresser (TVSS). A TVSS rated at 80kA (8x20 microsecond current waveform) surge capability or greater, suitable for location category C3 per IEEE C62.41-1991, and providing protection L_L and L_N shall be installed on the load side of the first disconnecting means or overcurrent device of the derived systems. The ground bus at the first disconnecting means or overcurrent device shall be bonded to the junction level main ground plate established in accordance with the requirements of this paragraph. This connection shall not be in lieu of the grounding electrode conductor requirements of NEC article 250-26.

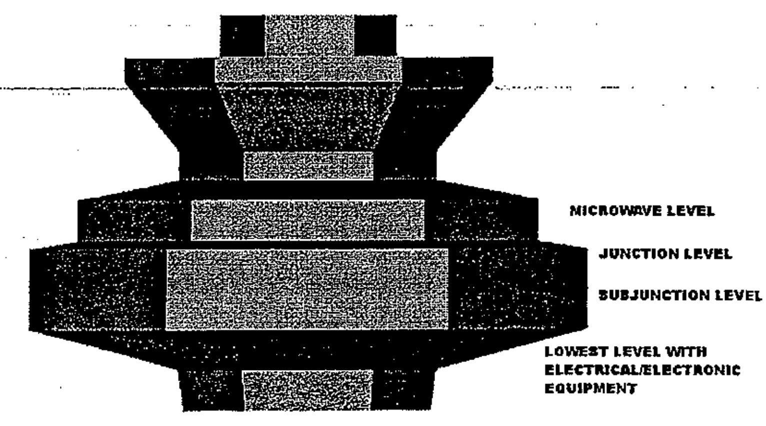


Figure 3

3.9.13.3 Roof, structural steel, reinforcing, and other metal element bonding. Metal elements composing the ATCT roof and its supporting structure, reinforcing bar in both horizontal and vertical elements, building steel, and metal sheathing shall be bonded together so as to provide a "Faraday Cage". Particular care shall be taken to insure that all penetrations of the Faraday cage are bonded to the cage at their point of entry. All reinforcing bar within the tower shaft shall be tied together and where independent elements are used the reinforcing bars shall be tied between elements at least once per 4 feet. Reinforcing bars in the floors, overheads corrugated decking, and footers shall likewise be tied to the reinforcing in the vertical elements. This bonding is necessary to establish both the Faraday Cage and to provide a secondary-grounding path for high frequency equipment.

3.9.13.4 Signal, Communications, Coaxial Cables and Control Line Protection. For purposes of lightning and transient protection cables running up the tower shaft in open raceways are considered totally exposed to lightning related phenomenon. For this reason transient protection must be applied at each end of these cables. This protection shall be installed where the cables enter the equipment room near the top of the ATCT and where they enter the associated base building. Both facility and equipment levels of protection shall be established for these lines.

3.9.13.5 Signal Grounding. The signal grounding system for the ATCT cab and associated electronic equipment rooms consist of both single point and multipoint elements. The single point grounding system is most frequently used in conjunction with the audio and associated switching equipment. The multipoint ground system is used for most other electronic equipment. All grounds present within the operational or equipment levels shall be bonded together on the sub-junction level with electrical, electromechanical, or electronic equipment.

3.9.13.6 Multipoint ground. A multipoint ground system consisting of either a raised access floor with below floor signal reference grid (SRG) or, where a raised access floor is not used, a copper sheet equipotential plane (EPP) shall be installed in:

a) All facility operational equipment areas

b) All other areas containing electronic equipment supporting facility operations.

The above operational and electronic equipment - and all electrical equipment in those areas - shall be bonded to the SRG or EPP installations in the area. In turn, all installed SRG's and EPP's - on the same floor and on different floors - shall be bonded together.

c) Any area containing electrical equipment installed to address power quality (e.g., isolation transformers, power conditioning equipment, etc.) not in the same area as the operational or electronic equipment (on different floors, etc.) shall be bonded to the SRG/EPP system.

The SRG shall consist of 2" wide copper straps arranged in a grid on 2' centers. Connections from the SRG to the access floor pedestals shall be on a six foot spacing. The EPP shall consist of copper sheets bonded to each other by overlapping 6" of the sheet material along all joints and securing with a conductive adhesive. Floor coverings of either tile or carpeting shall be of static dissipative material that is properly installed per manufacturers' specifications and connected to a component of the Multipoint Ground (MPG) system or to the Signal Reference Grid (SRG). The floor covering should have a surface-to-surface Resistivity (Rtt) of between 25 Kilo Ohms ($2.5x10^4$ Ω) per square (minimum) and 100 Megohms ($1x10^8$ Ω) per square (maximum) and be tested at a minimum semiannually in accordance with the test method specified in ANSI/ESD S7.1-1994, "Floor Materials --Resistive Characterization of Materials." Individual areas of the multipoint ground system on a single floor shall be bonded to adjacent areas via at least two separate paths providing a minimum of 2 ft^2 of surface area per lineal foot of conductor per path. The grounding system on each floor with electrical, electromechanical, or electronic equipment shall be bonded to adjacent floors via at least two separate paths providing a minimum of 2 ft^2 of surface area per lineal foot of conductor per path.

3.9.13.7 Single point grounding. Single point ground systems, if required for the electronic equipment to be installed, shall be constructed in accordance with paragraph 3.12 of this document. All single point ground systems and independent ground systems mandated by equipment manufacturers shall be bonded either directly to the earth electrode system (EES) or to the junction level main ground plate established in accordance with the requirements of this paragraph. All electronic grounding systems at a facility shall be bonded together to prevent the possibility of large voltage differentials between equipment during a lightning strike.

3.10 Earth electrode system requirements

3.10.1 General. An earth electrode system shall be installed at each facility to provide a low resistance to earth for lightning discharges, electrical and electronic equipment grounding, power fault currents and surge and transient protection. The earth electrode system shall be capable of dissipating within the earth the energy of direct lightning strikes with no ensuing degradation to itself. The system shall dissipate DC, AC and RF currents from equipment and facility grounding conductors. The system shall also be capable of conducting power system fault currents to earth for the time required to operate protective devices.

3.10.2 Site survey. A site survey shall be made to determine its relevant geological and physical characteristics. Information shall be obtained regarding the location of rock formations, gravel deposits and soil types in the immediate vicinity. In addition, the survey shall determine frost line depth, the depth and variations of the water table and the locations of buried metallic objects such as pipe lines and storage tanks. Soil resistivity measurements shall be made at distances of 10, 20, 30, and 40 ft. (3, 6, 9 and 12 m) in four directions from the proposed facility. All survey data, including soil resistance measurements, shall be noted on a scaled drawing or sketch of the site. Guidelines are provided in FAA Orders 6950.19 and 6950.20.

3.10.3 Design. The earth electrode system shall normally consist of driven ground rods, buried interconnecting cables and connections to underground metallic pipes, tanks and structural members of buildings that are effectively grounded. The design goal for the resistance to earth of the earth electrode system shall be as low as practicable, and not over 10 ohms unless otherwise specified in the contract document. Where conditions are encountered, such as rock near the surface, designs for optimum grounding using copper plates installed to slope away from structure as steep as possible and/or horizontal grids of conductors as a counterpoise plane shall be used in lieu of driven ground rods.

3.10.4 Configuration. Unless otherwise specified, the earth electrode system shall consist of at least four ground rods that penetrate to the lowest resistance as determined by the site survey, see Para. 3.10.2 and 3.10.3. At facilities that have two or more structures, i.e. a building and antenna tower, separated by 15 ft. (4.5 m) or less, one earth electrode system surrounding both structures shall be provided. Where structures are separated by more than 15 ft. (4.6 m) but less than 30 ft. (8.2 m), the earth electrode system may share a common side. Where the structures are separated by more than 30 ft. (8.2 m) an earth electrode system shall surround each structure and the earth electrode systems shall be interconnected by at least one buried cable. Guidelines are provided in FAA Orders 6950.19 and 6950.20.

3.10.5 Ground rods. Ground rods and their installation shall meet the following requirements.

3.10.5.1 Material and size. Ground rods shall be copper or copper clad steel, a minimum of 10 ft. (3 m) in length and 3/4 in. (19 mm) in diameter. Rod cladding shall not be less than 1/64 in. (19 mm) thick.

3.10.5.2 Spacing. Ground rods shall be as widely spaced as practical, and in no case spaced less than one rod length. Nominal spacing between rods should be between two and three times rod length.

3.10.5.3 Depth of rods. Tops of ground rods shall be not less than 1 ft. (0.3 m) below grade level.

3.10.5.4 Location. Ground rods shall be located 2 to 6 ft. (0.6 to 1.8 m) outside the foundation or exterior footing of the structure. On buildings with overhangs ground rods may be located further out.

3.10.6 Interconnections. Ground rods shall be interconnected by a buried, bare, No. 4/0 AWG stranded copper cable. The cable shall be buried at least 2 ft. (0.6 m) below grade level. Connections to the ground rods shall be made by exothermic welding or other FAA approved method as specified herein. The interconnecting cable shall close on itself forming a complete loop with the ends exothermically welded or connected with an FAA approved hydraulically crimped pressure connector. The structural steel of buildings shall be connected to the earth electrode system at approximately every other column at intervals averaging not over 60 ft. (18.3 m) with a bare, No. 4/0 AWG stranded copper cable. Connections shall be by exothermic welds. The grounding electrode conductor for the electric service, sized in accordance with the NEC requirement for grounding electrode conductors, shall not be smaller than No. 6 AWG and shall be connected to a ground rod in the earth electrode system with an exothermic weld or FAA approved pressure connector. All underground metallic pipes and tanks, and the telephone ground, if present, shall be connected to the earth electrode system by a copper cable no smaller than No. 2 AWG. Where routed underground, interconnecting cables shall be bare. Exothermic welds shall not be used where hazards exist, i.e. near fuel tanks. In these cases, connections using FAA approved pressure connectors will be allowed. Bonding resistance of all interconnections shall be one (1) milliohm or less for each bond when measured with a 4-terminal milliohm meter.

3.10.7 Access well. Access wells are permissible at facilities. The well should be located at a ground rod that is in an area with access to open soil so that checks of the earth electrode system can be made once the facility is in use. The access well shall be made from clay pipe, poured concrete, or other approved wall material and shall have a removable cover. The access well shall have a minimum opening area of 175 square inches and be of sufficient size to allow ground rod connections to be readily disconnected and reconnected. These connections shall be by FAA approved exothermic welds, hydraulically crimped, explosively crimped, or bolted pressure connectors per Paragraphs 3.14.5 and 3.14.6.

3.11 Electronic multipoint ground system requirements. High densities of sensitive electronic equipment characterize FAA operational facilities. It is therefore mandatory that FAA operational facilities be grounded in accordance with the best design practices as described in ANSI/IEEE 1100-1992 "IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment." While this standard contains various techniques for constructing a multipoint ground system, it is important to note that all operations and electronic equipment rooms of new operational facilities shall have a high frequency (HF) ground referencing system constructed in accordance with the guidance provided in paragraph 9.10.13 and in particular 9.10.13.1.2 of ANSI/IEEE 1100-1992.

3.11.1 General. The protection of electronic equipment against potential differences and static charge buildup shall be provided by interconnecting all non-current-carrying metal objects to an electronic multipoint ground system that is effectively connected to the earth electrode system. The multipoint ground for electronic equipment systems consists of electronic equipment, racks, frames, cabinets, conduits, raceways, wireways, cable trays enclosing electronic conductors, structural steel members, and conductors used for interconnections. The electronic multipoint ground system shall also provide multiple low impedance paths between various parts of the facility, electronic equipment within the facility, and any point within the system and the earth electrode system to minimize the effects of spurious currents that may be present in the ground system. It is essential that no power or single point grounds utilize this system. The multipoint ground system is also not to be used as a signal return path. A typical ground system is shown in Figure 3, "Facility Ground System Configuration".

3.11.1.1 Raised floors. Electronic equipment rooms may utilize a properly bonded, electrically continuous, grounded raised floor, consisting of bolted grid (stringer) or rigid grid system, as part of an electronic multipoint grounding system. The raised floor may then be used as part of an equipotential surface for the electronic equipment in the room.

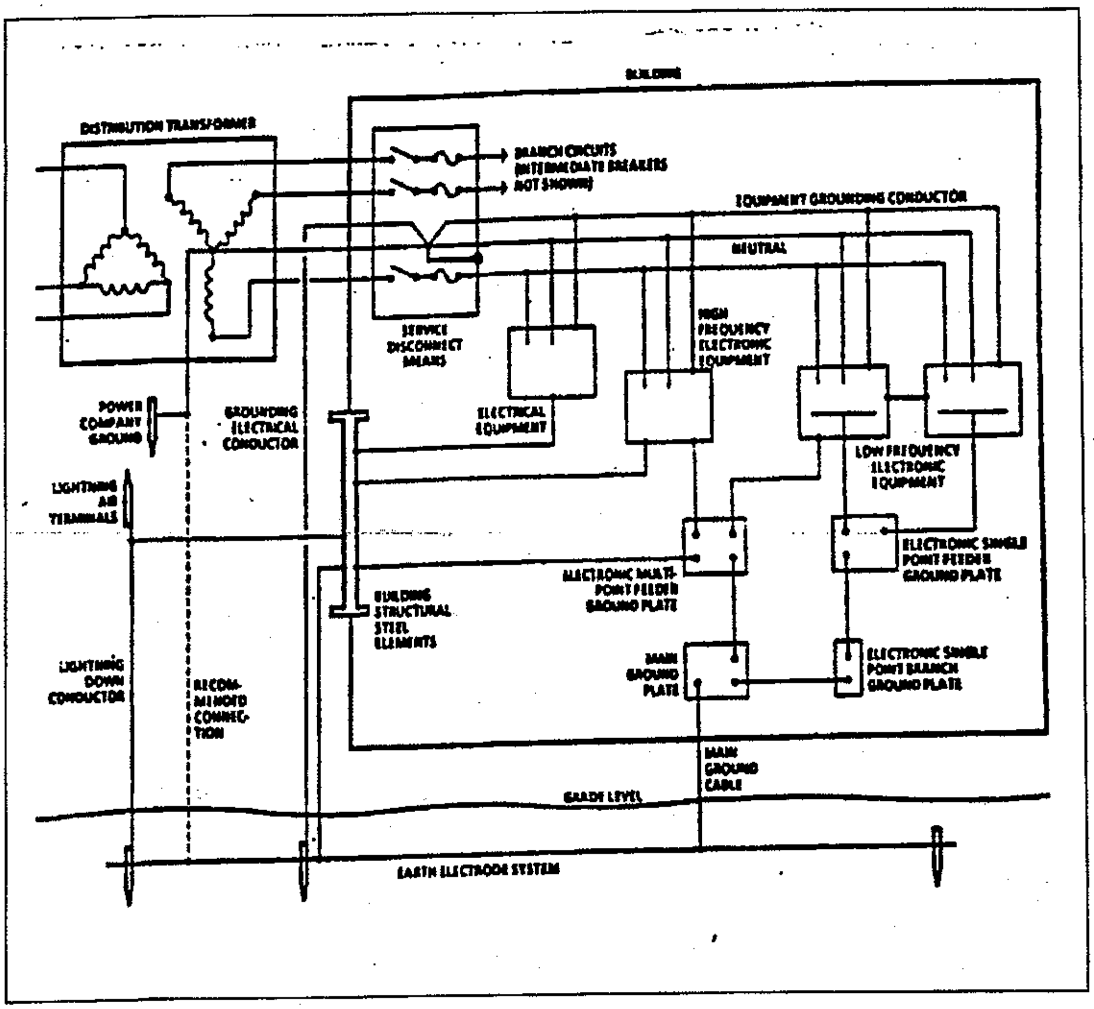


Figure 4 Facility Ground System Configuration

3.11.2 Ground plates, cables and protection. The electronic multipoint ground system shall not replace the equipment grounding conductor routed with the phase and neutral conductors as required by the NEC. At least two connections between the multipoint ground system and the earth electrode system shall be provided. One connection shall be provided by a 500 MCM or equivalent copper cable connected between the main ground plate and the earth electrode system. In buildings without structural steel members, a second connection shall be provided by a 500 MCM or equivalent copper cable connected between the earth electrode system and a supplemental ground plate on the opposite side of the facility. The cable shall be exothermically welded to the earth electrode system and bolted to the ground plate or bus with a UL approved connector. Connection points shall be chosen to minimize cable length, but shall not exceed 50 feet. In steel structures, additional connections shall be made between each ground plate or bus and the structural steel.

3.11.2.1 Ground plates and buses. A ground plate shall be used when a centralized connection point is desired. The location shall be chosen to facilitate the interconnection of all equipment cabinets, racks and cases within a particular area. If more than one ground plate is required, they shall be installed at various locations within the facility. Ground buses shall be used when distributed grounding is desired with a long row of equipment cabinets. Ground plates shall be copper and at least 6 in. (152 mm) long, 4 in. (102 mm) wide and 1/4 in. (6.4 mm) thick. Ground bus width and thickness shall be selected from Table IV, Size of Electronic Multipoint Ground Cables, according to the length required. Ground plates and buses shall be identified with a permanently attached plastic or metal label that is predominantly green with distinguishing bright orange slashes. The label shall bear the caption "ELECTRONIC MULTIPOINT GROUND SYSTEM" in black 3/8-in. high (10 mm) characters.

3.11.2.2 Ground cables. Interconnections in the electronic multipoint ground system between ground plates and buses and between ground plates and structural steel shall be made with stranded copper cable conforming to Table IV. These cables shall be color coded green with a bright orange tracer or shall be clearly marked for 4 in. at each end and wherever exposed with a green tape overlaid with a bright orange tracer. Where routed through raceways or wireways, the color coding shall be visible by opening any cover. Where conductors are routed through cable trays, color coding 4 in. long shall be provided at intervals not exceeding 3 ft.

Cable Size	Max. Path Length		Bus Bar Size		Max. Path Length	
	Ft.	(m)	Inch	(mm)	Ft.	(m)
750 MCM*	375	(114.3)	4 x 1/4	(100 x 6.4)	636	(193.9)
600 MCM*	300	(91.4)	4 x 1/8	(100 x 3.2)	318	(96.9)
500 MCM	250	(76.2)	3 x 1/4	(75 x 6.4)	476	(145.1)
350 MCM	175	(53.3)	3 x 1/8	(75 x 3.2)	238	(72.5)
300 MCM	150	(45.7)	2 x 1/4	(50 x 6.4)	318	(96.9)
250 MCM	125	(38.1)	2 x 1/8	(50 x 3.2)	159	(48.5)
4/0 AWG	105	(32.0)	2 x 1/16	(50 x 1.6)	79	(24.1)
3/0 AWG	84	(25.6)	1 x 1/4	(25 x 6.4)	159	(48.5)
2/0 AWG	66	(20.1)	1 x 1/8	(25 x 3.2)	79	(24.1)
1/0 AWG	53	(16.2)	1 x 1/16	(25 x 1.6)	39	(11.9)
1 AWG	41	(12.5)				
2 AWG	33	(10.1)				
4 AWG	21	(6.4)				
6 AWG	13	(4.0)				
8 AWG	8	(2.4)				

NOTE: MCM* - Where these cables are not available, parallel cables may be used such as three 250 MCM cables in place of one 750 MCM cable, or two 300 MCM cables in place of one 600 MCM cable.

Table IV Size of Electronic Multipoint Ground Cables

3.11.2.3 Protection. Provide mechanical protection for all cables in the electronic multipoint ground system where they may be subject to damage. This protection may be provided by conduit, floor trenches, routing behind permanent structural members, or other means as applicable. Where routed through metal conduit, the conduit shall be bonded to the cable at each end.

3.11.3 Building structural steel. All structural members such as building columns, wall frames, roof trusses of steel frame buildings and other metal structures shall be made electrically continuous by bonding each joint and interconnection in accordance with Para. 3.14.9.4. The structural steel shall be connected to the earth electrode system as specified in Para. 3.10.6.

3.11.3.1 Metal building elements. The requirements of this paragraph apply to facilities which have sensitive receiver or computing systems and are located in areas where radiation from radar or other high power transmitters is expected. Metal building elements and attachments such as walls, roofs, floors, door and window frames, gratings and other architectural features shall be directly bonded to structural steel in accordance with Para. 3.14.9.4. Where direct bonding is not practical, indirect bonds with copper cable conforming to Table IV shall be employed. Removable or adjustable parts and objects shall be grounded with an appropriate type bond strap as specified in Para. 3.14.7. All bonds shall conform to the requirements of Para. 3.14. Metal elements with a maximum dimension of 3 ft. (0.9 m) or less are exempt from the requirements of this paragraph.

3.11.4 Interior metallic piping systems. The interior metallic cold water piping system shall be bonded to the service disconnecting means ground point or to the earth electrode system. The bonding jumper shall be sized in accordance with the NEC. All other interior metallic piping which may become energized shall be bonded as specified for equipment grounding conductors. The bonding jumper shall be sized in accordance with the NEC using the rating of the circuit which may energize the piping.

3.11.4.1 Ground connections. Clamps providing continuous follow-up pressure shall be used to bond pipes and tubes to the equipment ground system. In highly humid or corrosive atmospheres, adequate protection against corrosion shall be provided in accordance with Para. 3.14.14.

3.11.5 Electrical supporting structures. All metallic electrical support structures shall be electrically continuous and shall be directly bonded to the electronic multipoint ground system and to the earth electrode system.

3.11.5.1 Conduit. All metal conduit used for electronic signal and control wiring shall be grounded as follows:

(a) All joints between conduit sections and between conduit, fittings, and boxes shall be electrically continuous. All pipe and locknut threads shall be treated with a conductive lubricant prior to assembly. Surfaces shall be prepared in accordance with Para. 3.14.13. Joints that are not otherwise electrically continuous shall be bonded with short jumpers of No. 12 AWG or larger copper wire. The jumpers shall be welded or brazed in place or shall be attached with clamps, split bolts, grounding bushings, or other devices approved for the purpose. All bonds shall be protected against corrosion in accordance with Para. 3.14.14.

(b) Cover plates of conduit fittings, pull boxes, junction boxes, and outlet boxes shall be grounded by securely tightening all available screws.

(c) Every component of metallic conduit runs such as individual sections, couplings, line fittings, pull boxes, junction boxes and outlet boxes shall be bonded, either directly or indirectly, to the electronic multipoint ground system or facility steel at intervals not exceeding 50 ft. (15 m).

(d) Conduit brackets and hangers shall be securely bonded to the conduit and to the metal structure to which they are attached.

3.11.5.2 Cable trays and wireways. The individual sections of all cable tray systems for electronic conductors shall be bonded together and each support bracket or hanger shall be bonded to the cable trays which they support. All bonds shall be in accordance with the procedures and requirements specified in Para. 3.14. All tray assemblies for electronic conductors shall be connected, either directly or indirectly, to the electronic multipoint ground system or properly grounded facility steel within 2 ft. (0.6 m) of each end of the run and at intervals not exceeding 50 ft. (15 m). The resistance of each of these connections shall not exceed 5 milliohms.

3.11.6 Secure facilities. In all areas of facilities required to maintain communications security, equipment and power systems shall be grounded in accordance with NACSIM-5203.

3.12. Electronic single point ground system requirements

3.12.1 General. The electronic single point ground system shall be isolated from the electronic multipoint ground system, power grounding system and lightning protection system. The electronic single point ground system shall be terminated at the main ground plate or to the earth electrode system. The network shall be configured to minimize cable lengths. Conductive loops in the network shall be avoided by maintaining a trunk and branch arrangement as shown in Figure 4 and Figure 5, "Electronic Single Point Ground System Installation".

3.12.2 Ground plates. Main, branch and feeder ground plates shall be of copper and at least 6 in. (152 mm) long, 4 in. (102 mm) wide, and 1/4 in. (6.4 mm) thick. The plates shall be mounted on phenolic or other non-conductive material of sufficient cross section to rigidly support the plates after all cables are connected. Bolts or other devices used to secure the plates in place shall be insulated or shall be of a non-conducting material. The plates shall be mounted in a manner that provides ready accessibility for future inspection and maintenance.

3.12.3 Isolation. The minimum resistance between the electronic single point ground and the electronic multipoint ground systems shall be 10 megohms. The resistance shall be measured after the complete network is installed and before connection to the earth electrode system or to the electronic multipoint ground system at the main ground plate.

3.12.4 Resistance. The maximum resistance between any ground plate and any cable connected to the plate shall not be greater than 1 milliohm.

3.12.5 Ground cable size. The size of the main, trunk and feeder ground cables shall be as follows:

3.12.5.1 Main ground cable. An insulated copper cable shall be installed from the isolated ground lug at the electronic equipment, or from single point feed or branch ground plates to the main ground plate or the earth electrode system. The conductor shall be sized in accordance with para.3.12.5.3 Branch ground cables. This cable shall be routed as shown on the facility drawings. One end of the cable shall be exothermically welded to the earth electrode

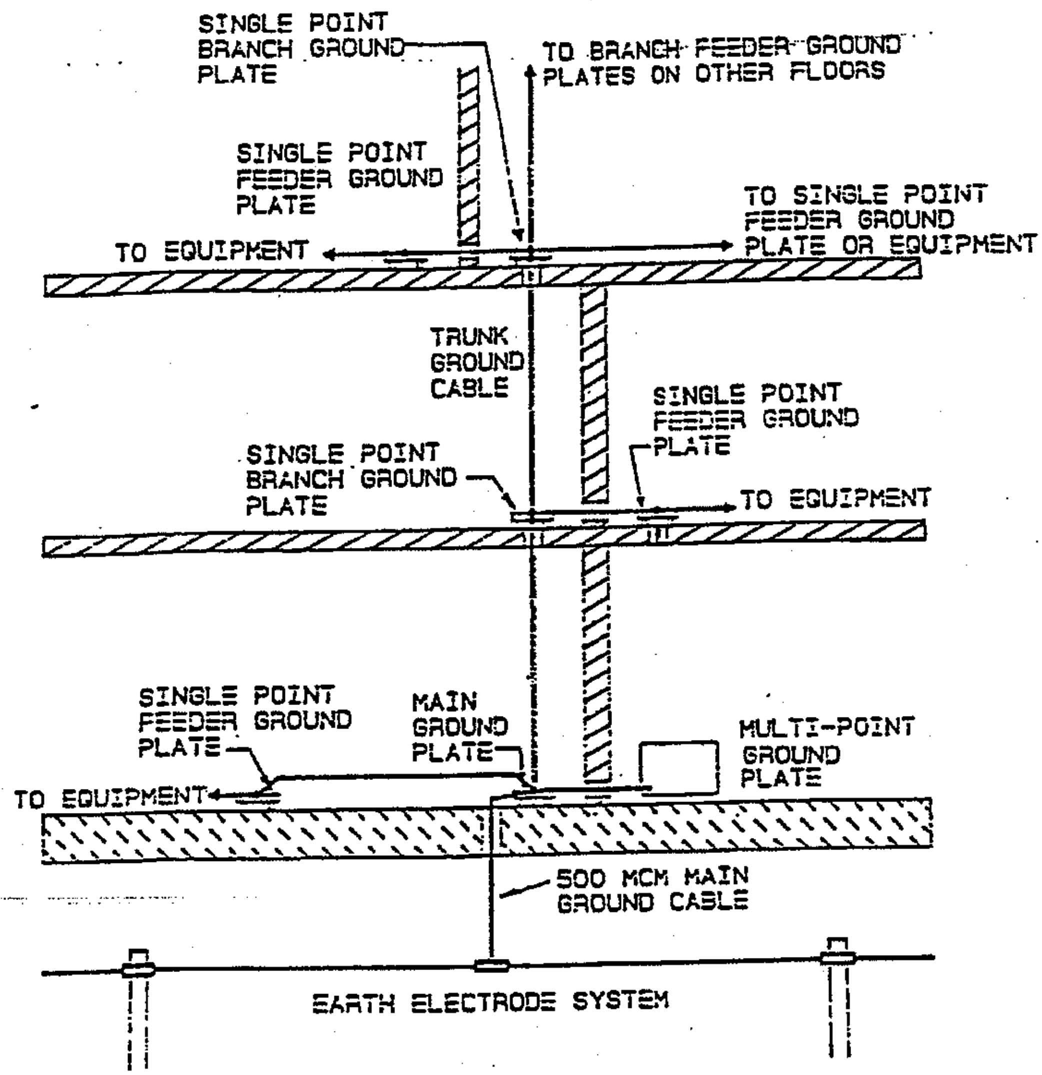


Figure 5 Electronic Single Point Ground System Installation

system. The other end shall be bolted to the main ground plate in accordance with Para. 3.14.6. This cable shall be mechanically protected by enclosing it in PVC conduit or by routing it in other non-metallic material, in floor trenches or behind permanent structural members.

3.12.5.2 Trunk ground cables. An insulated trunk ground cable shall be installed in each facility from the main ground plate to each of the branch plates as shown in Figure 4. This cable shall be 4/0 for lengths up to 400 ft. For longer runs, select a cable size based on providing a cross sectional area of 500 cmil per running foot of cable length. Trunk ground cables shall be bolted to the ground plates in accordance with Para. 3.14.6 and shall be mounted as shown on the facility drawings. Trunk ground cable protection shall be identical to that required for main ground cable, see Para. 3.12.5.1.

3.12.5.3 Branch ground cables. Insulated copper branch ground cables shall be installed between feeder and branch ground plates. These cables shall be routed to provide the shortest practical path. Branch ground cables shall be No. 2 AWG for lengths less than 75 ft. (22.9 m) and 1/0 AWG for lengths between 75 ft. and 150 ft. (45.7 m). A No. 4/0 AWG cable shall be used for lengths greater than 150 ft. Branch ground cables shall be bolted to the feeder and branch ground plates in accordance with Para. 3.14.6. Branch ground cable protection shall be identical to that required for main ground cable, see Para. 3.12.5.1.

3.12.5.4 Electronic equipment ground cables. The cable from the feeder ground plate (branch ground plate if there is no need for a feeder ground plate in the cable run) to the isolated terminal or bus on the electronic equipment shall also meet the 500 cmil per running foot requirement. The minimum size cable shall be an insulated No. 16 AWG for cable lengths not more than 5 ft. For runs over 5 ft. the cable size shall be increased accordingly. Runs up to 10 ft. shall be No. 12 AWG minimum. Care shall be taken to locate a ground plate close to the electronic equipment so that cable size may be kept small enough to avoid problems with connections to electronic equipment.

3.12.5.5 Interconnections. All connections to the single point ground system shall be made on ground plates or buses. Split bolts, Burndy clamps and other connections to existing cables are not allowed.

3.12.6 Labeling. The single point ground system shall be clearly labeled to preserve its integrity as described in the following sections.

3.12.6.1 Cables. Trunk, branch and electronic equipment ground cables shall be color coded green with a bright yellow tracer. Where cables are concealed and not color coded, any exposed portion of the cable and each end of the cable for a minimum length of 2 ft. (0.6 m) shall be color coded by green tape overlaid with bright yellow tape to form the tracer. Where routed through raceways or wireways, color coding shall be visible by opening any cover. Where conductors are routed through cable trays, color coding 4 in. in length shall be applied at intervals not exceeding 3 ft.

3.12.6.2 Ground plates. All ground plates shall be provided with a clear plastic protective cover spaced 3/4 in. (19 mm) from the plate and extending 1 in. (25.4 mm) beyond each edge. This cover shall have a green label with distinguishing bright yellow slashes attached bearing the caption: "CAUTION, ELECTRONIC SINGLE POINT GROUND" in black 3/8-in. high (10 mm) characters.

3.13 National Electrical Code (NEC) grounding compliance.

3.13.1 General. The facility electrical grounding shall comply with the grounding requirements of Article 250 of the NEC and as specified herein. The electronic multipoint ground system shall not replace the equipment grounding conductor required by the NEC.

3.13.2 Grounding electrode conductors. Grounding electrode conductors shall conform to the following:

(a) Premises wiring required by the NEC to be grounded shall have the identified (neutral) conductor connected to the earth electrode system by a copper grounding electrode conductor at the service disconnecting means and by an additional copper grounding conductor from the neutral of the transformer secondary to a grounding electrode. The grounding electrode conductor shall be sized in accordance with the NEC, but in no case shall the wire size be smaller than No. 6 AWG.

(b) The grounding connection for services shall be made at the service disconnecting means.

(c) The grounding electrode conductor connecting the identified neutral wire (grounded conductor) to the earth electrode system shall be continuous and unspliced, except where splices and taps are permitted by the NEC (busbars and services consisting of more than a single enclosure). When a grounding electrode conductor is routed through a metal enclosure, e.g., conduit, the enclosure shall be bonded at each end to the grounding electrode conductor.

(d) Where two or more facilities are separately supplied by a common service, the grounded conductor shall be connected to the earth electrode system at each facility on the supply side of the disconnecting means. The grounded conductor shall not be grounded at other points within the facility.

(e) Where one facility receives its electrical power from another facility, the equipment grounding conductor shall be carried with the phase and neutral conductors in the same conduit or raceway and the grounded conductor (neutral) of the receiving facility shall not be grounded at that facility.

(f) For separately derived systems, other than the primary facility service, the grounded conductor (separately derived system neutral), i.e. transformer secondary neutral, shall be connected directly to the earth electrode system if feasible. The required connections shall be made only at one point on the separately derived system, before any system disconnecting means or over-current device, and at one point on the earth electrode system. This grounded conductor extension shall be copper and sized in accordance with NEC requirements, except that this conductor shall not be smaller than No. 6 AWG. In addition, the grounded conductor shall be bonded to the frame and case of the separately derived system. Equipment grounding conductors (safety grounds) shall also be connected between the separately derived system ground connection to the case and (1) its supply side distribution panel ground bus, and (2) its load side disconnecting means enclosure ground connection. These equipment grounding conductors shall be green insulated, unspliced and sized in accordance with NEC requirements. No neutral-to-ground connection shall be made at the load side disconnecting means enclosure.

3.13.3 Equipment grounding conductors. Equipment grounding conductors shall be installed in all branch circuits and feeders in accordance with FAA-C-1217 and the following:

(a) Where required for the possible reduction of electrical noise, receptacles shall be permitted in which the grounding terminal is purposely isolated from the receptacle mounting box. The receptacle grounding terminal shall be grounded by an insulated equipment grounding conductor run with the other circuit conductors (phase and neutral). This grounding conductor shall be permitted to pass through one or more panel boards without connection to these panel board ground terminals. This equipment grounding conductor shall terminate directly at the applicable derived system or service ground terminal. A second insulated equipment grounding conductor shall be installed from the metal outlet box to the panel board feeding this receptacle. This conductor shall be bonded at one end to the metal outlet box and connected at the other end to the ground bus in the panel feeding the isolated receptacle. Both equipment grounding conductors shall be run in the same conduit with their associated phase and neutral conductors.

(b) Equipment grounding conductors shall be sized in accordance with the NEC.

(c) Grounding terminals in all receptacles on wire mold or plug mold strips shall be hardwired to an equipment grounding conductor. Strips that depend upon serrated or toothed fingers for grounding shall not be used.

3.13.4 Color coding of conductors

3.13.4.1 Ungrounded conductors. The color coding of ungrounded conductors shall be consistent throughout the facility as follows:

(a) For two ungrounded 120/240V conductors, colors shall be black and red.

(b) For three ungrounded 120/208V service conductors, colors shall be black, red, and blue for phase A, B and C respectively. For 277/480V service, colors shall be yellow, brown and orange for phases A, B and C respectively.

(c) Where color coded conductors larger than No. 6 AWG are not available, other colors, except white, natural gray or green, may be used if they are re-identified as specified above with tape or paint.

(d) When ungrounded conductors are re-identified, color coding shall be applied at each end and at every point where the conductor is accessible. When routed through raceways or wireways, the coding shall be visible by opening any cover. When conductors are routed through cable trays, coding 3 in. (75 mm) in length at intervals not exceeding 3 ft. (0.9 m), shall be provided.

3.13.4.2 Grounded conductors. Color coding of grounded conductors shall be consistent throughout the facility as follows:

(a) Neutral conductors (grounded conductors) shall be insulated and color coded white for 120/208V and natural gray for 277/480V. Conductors larger than No. 6 AWG may be re-identified as the grounded (neutral) conductor except that green conductors shall not be re-identified. Re-identification of conductors is permitted only if proper color coded wire is not available.

(b) In any room, conduit, pullbox, raceway, wireway, or cable tray, where two or more grounded conductors of different systems are present (branch circuits, feeders, services, voltages, etc.), the grounded conductors shall be clearly identified. The identification of the grounded conductors for each system shall be consistent throughout the facility. The grounded conductor of one system may be white, natural gray or re-identified. The grounded conductors of the other systems shall be identified by paint, tape or by an identifiable colored stripe, not green, on white insulation.

(c) Color coding of grounded conductors shall be applied at each connection and at every point where the conductor is accessible. Where routed through raceways or wireways, the color coding shall be visible by removing or opening any cover. Where conductors are routed through cable trays, color coding 3 in. (75 mm) in length shall be provided at intervals not exceeding 3 ft. (0.9 m).

3.13.4.3 Color coding of equipment grounding conductors. Equipment grounding conductor color coding shall be consistent throughout the facility as follows:

(a) Electrical equipment grounding conductors shall be solid green in color. Insulated conductors larger than No. 6 AWG may be re-identified with green paint or tape. White or natural gray conductors shall not be re-identified as equipment grounding conductors.

(b) Color coding of equipment grounding conductors shall be applied at each connection and at every point where the conductor is accessible. Where routed through raceways or wireways, the coding shall be visible by removing or opening any cover. Where conductors are routed through cable trays, color coding 3 in. long shall be provided at intervals not exceeding 3 ft. (0.9 m).

3.13.5 Conductor routing. The neutral (grounded conductor) and equipment grounding conductors shall be routed through the same conduit, raceway, wireway or cable tray as the phase conductors. Power conductors shall not be routed in the same conduit or enclosed raceway with control, communications, or signal conductors or cables. Where power cables must be routed in the same cable tray with electronic cables, the power conductors shall be twisted in accordance with Table V, Minimum Number of Twists for Power Conductors. For conductor sizes larger than No. 2 AWG, the conductors shall be twisted to the maximum extent practical.

3.13.6 Non-current-carrying metal equipment enclosures. Metal enclosures shall meet the following requirements:

(a) All non-current-carrying metal enclosures such as conduit, raceways, wireways, cable trays and panel boards shall be electrically continuous. Insulating finishes shall be removed between grounding areas of mating surfaces or bonding jumpers shall be used. Where bonding jumpers are used, the surface between the jumper and part to be bonded shall be cleaned of insulating finishes. Conduits shall employ bonding-type locknuts tightened sufficiently to cut through any surface coating, or shall employ grounding clamps or bushings.

Table V MINIMUM NUMBER OF TWISTS FOR POWER CONDUCTOR

Size (AWG)	Twists per foot (0.3 m)			
	No. of Conductors			
	Two	Three	Four	Five
12	7	5	4	3
10	6	4	3	2.5
8	5	4	3	2
6	4	3	2	1.5
4	3	2	1.5	1
2	2.5	2	1.5	1

(b) Maximum use shall be made of ferrous materials for conduit, raceways, wireways and cable trays to provide shielding from the magnetic fields produced by power conductors.

3.14 Bonding requirements

3.14.1 Resistance. Unless otherwise specified in this standard, all bonds shall exhibit a resistance of 1 milliohm or less when measured between the bonded members with a 4-terminal milliohmmeter.

3.14.2 Methods. Unless otherwise specified, welded or brazed bonds shall be used. The surface contact area of bolted connections to flat surfaces in the lightning protection system shall be 3 square inches or greater. Soft soldered or brazed connections shall not be used for any part of the power grounding system or the lightning protection system (air terminals, roof conductors, down conductors, fasteners, and conduit). Soft solder shall only be used to improve conductivity at load bearing joints. Soft solder shall not be used to provide mechanical restraint.

3.14.3 Exothermic welds. Exothermic welds may be used for any type of bond connection specified herein. Exothermic welds are preferred for all underground connections between earth electrodes, counterpoise cable and other connections to the earth electrode system. Exothermic welds may not be possible between certain materials or shapes.

3.14.4 Welds. Welds shall meet the following minimum requirements.

(a) Welds shall support the mechanical load demands on the bonded members.

(b) On members with a maximum dimension of 2 in. (50.8 mm) or less, the weld shall extend completely across the side or surface of the largest dimension.

(c) On members with a maximum dimension between 2 in. (50.8 mm) and 12 in. (305 mm), one weld of at least 2 in. in length shall be provided.

(d) On members with a dimension of 12 in. (305 mm) or more, two or more welds, each not less than 2 in. (50.8 mm) in length shall be provided at uniform spacings across the surface. The maximum spacing between welds shall not exceed 12 in.

(e) At butt joints, complete penetration welds shall be used on all members whose thickness is 1/4 in. (6.4 mm) or less. Where the thickness of the members is greater, the depth of the weld shall be more than 1/4 in.

(f) Fillet welds shall have an effective size equal to the thickness of the members.

(g) At lap joints between members whose thickness is less than 1/4 in. (6.4 mm), double fillet welds shall be provided.

3.14.5 Brazing. Brazing shall be employed only in the electronic multipoint ground system as follows:

(a) Brazing or silver soldering may be used for the permanent bonding of copper conductors and copper alloy materials.

(b) Either brazing or exothermic welding shall be used for the permanent bonding of copper conductors to steel or other ferrous structural members.

(c) All residual fluxes shall be removed or neutralized to prevent corrosion.

(d) Brazing shall not be used for buried connections in the facility ground system.

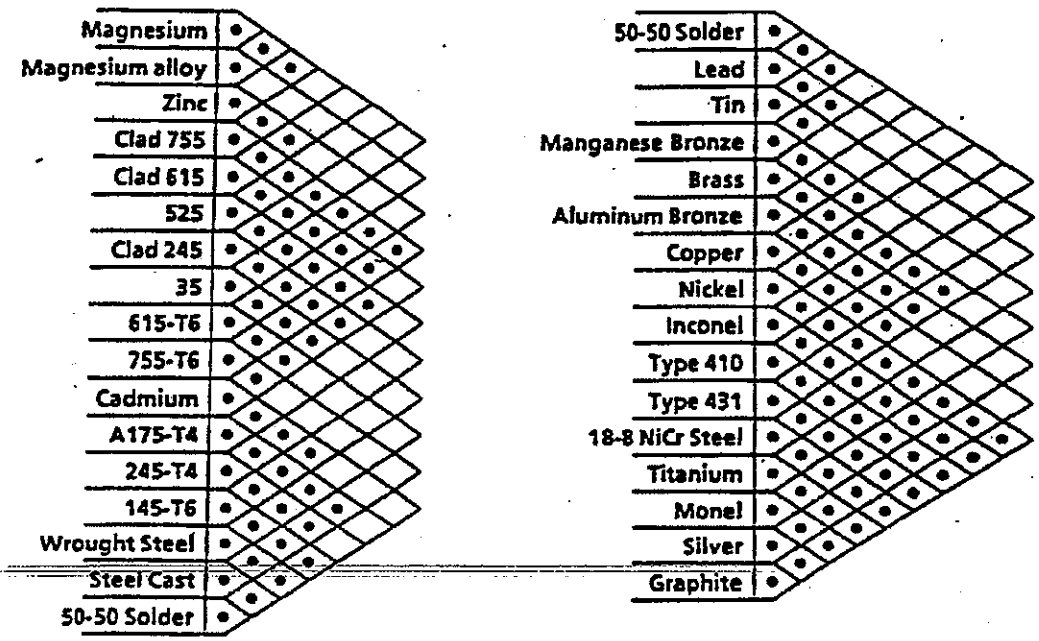
(e) Brazing material shall meet the requirements for dissimilar metals as specified in Table VI, Acceptable Couplings Between Dissimilar Metals.

3.14.6 Mechanical connections

3.14.6.1 Bolted connections. Bolted connections shall conform to the following:

(a) All bolted connections shall conform to the torque requirements in Table VII, Minimum Torque Requirements for Bolted Bonds.

Table VI ACCEPTABLE COUPLINGS BETWEEN DISSIMILAR METALS



Notes:

1. **Stainless steels, nickel, and inconel are considered passive on this chart.**
2. **Each metal on the chart is considered anodic (sacrificial) to the metals following it.**
3. **A solid dot (•) indicates an acceptable combination.**

(b) Bolted connections shall be assembled in the order shown in Figure 6, "Order of Assembly for Bolted Connections". Load distribution washers, if used, shall be positioned directly underneath the bolt head. Lockwashers shall be placed between the nut and the primary members. Washers shall not be placed between bonded members. (See Para. 3.14.13 for surface preparation.)

3.14.6.2 Hydraulically crimped. Mechanical connections using a Burndy "Hyground Connector" or equivalent when operated at a force of 24,000 pounds are acceptable as FAA approved pressure connectors. (These connectors are not acceptable in the lightning protection system.)

Table VII MINIMUM TORQUE REQUIREMENTS FOR BOLTED BONDS

Bolt Size	Threads/Inch	Min. Torque (in-lbs)	Tension (lbs)	Bond Area (sq. in.)
No. 8	32	18	625	0.416
	36	20	685	0.456
No. 10	24	23	705	0.470
	32	32	940	0.626
1/4 in.	20	80	1840	1.225
	28	100	2200	1.470
5/16 in.	18	140	2540	1.690
	20	150	2620	1.750
3/8 in.	16	250	3740	2.430
	24	275	3950	2.640
7/16 in.	14	400	5110	3.400
	20	425	5120	3.420
1/2 in.	13	550	6110	4.070
	20	575	6140	4.090
5/8 in.	11	920	7350	4.900
3/4 in.	10	1400	9300	6.200
7/8 in.	9	1950	11100	7.400
1 in.	8	2580	12900	8.600

3.14.6.3 Explosively crimped. Mechanical connections using an AMP "Copper Tap Connector" or equivalent are acceptable as FAA approved pressure connectors for above grade connections and in access wells. (These connectors are not acceptable in the lightning protection system.)

3.14.7 Bonding straps and jumpers. Bonding straps, including jumpers, shall conform to the following:

(a) Bonding straps shall be attached to the basic member.

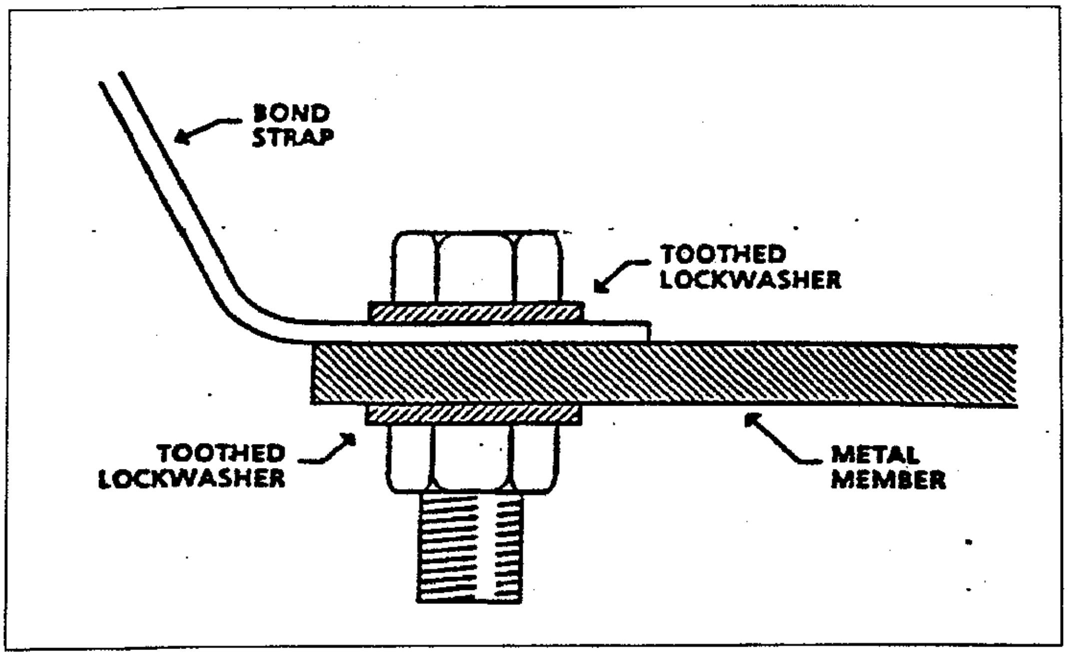


Figure 6 Order of Assembly for Bolted Connections

(b) Bonding straps shall be installed to be unaffected electrically by motion or vibration.

(c) Braided bonding straps shall not be used for bonding transmitters or other sources of RF fields.

(d) Bonding straps shall be installed whenever possible in areas accessible for maintenance.

(e) Bonding straps shall be installed so they will not restrict movement of the members being bonded or other members nearby which must be able to move as part of normal functional operation.

(f) Two or more bonding straps shall not be connected in series to provide a single bonding path.

(g) The method of installation and point of attachment of bonding straps shall not weaken the members to which they are attached.

(h) Bonding straps shall not be compression-fastened through non-metallic material.

3.14.8 Fasteners. Fastener materials for bonding aluminum and copper jumpers to structures shall conform to the materials listed in Table VIII, Metal Connections for Aluminum and Copper Jumpers.

3.14.9 Metal elements requiring bonding

3.14.9.1 Earth electrode risers. The earth electrode system shall be connected by exothermic welding to the down conductors of the Lightning Protection System, the Grounding Electrode Conductor, the grounding conductor from the Main Ground Plate of the electronics grounding system, and the conductors from the structural steel columns. Except for lightning protection down conductor terminations, other bonding connectors as specified in contract documents, e.g. hydraulically crimped connectors, may be used in place of exothermic welds. Explosively crimped connectors may be used in lieu of hydraulically crimped connectors where it is required that these connections be accessible, e.g. in access wells.

Table VIII METAL CONNECTIONS FOR ALUMINUM AND COPPER JUMPERS

Metal Structure (Outer Finish Metal)	Connection for Aluminum Jumper	Screw Type*	Tinned Copper Jumper	Screw Type*
Magnesium (Mg) and Mg Alloys	Direct or Mg washer	Type I	Aluminum (Al) or Mg washer	Type I
Al, Al alloys, Cadmium (Cd) and Zinc (Zn).	Direct	Type I	Al washer	Type I
Steel (except stainless steel)	Direct	Type I	Direct	Type I
Tin (Sn), Lead (Pb), and Sn-Pb solders	Direct	Type I	Direct	Type I or II
Copper (Cu) and Cu alloys	Tinned or Cd plated washer	Type I or II	Direct	Type I or II
Nickel (Ni) and Ni alloys	Tinned or Cd plated washer	Type I or II	Direct	Type I or II
Stainless Steel	Tinned or Cd plated washer	Type I or II	Direct	Type I or II
Silver, Gold and precious metals	Tinned or Cd plated washer	Type I or II	Direct	Type I or II

*Screw Type - Type I, Cadmium, zinc plated or aluminum
Type II, Passivated stainless steel

3.14.9.2 Counterpoise cables. Counterpoise cables shall be attached to ground rods in accordance with the requirements of Para. 3.10.6.

3.14.9.3 Underground metallic pipes and tanks. Underground metallic pipes and tanks shall be bonded to the earth electrode system in accordance with the requirements of Para. 3.10.6.

3.14.9.4 Steel frame buildings. Structural members (columns, wall frames, and roof trusses) shall be electrically continuous. Where joints are not electrically continuous, they shall be bridged to obtain continuity, such as with a brazed or welded No. 4/0 AWG stranded copper cable.

3.14.9.5 Interior metallic pipes. Interior metallic pipes and conduits shall be bonded in accordance with Para. 3.11.4.

3.14.9.6 Electrical supporting structures. Conduit and cable trays shall be bonded in accordance with Para. 3.11.5.

3.14.9.7 Flat bars. Flat bars shall be bonded by high compression bolts.

3.14.10 Temporary bonds. Alligator clips and other spring loaded clamps shall be employed only as temporary bonds while performing repair work on equipment or facility wiring.

3.14.11 Inaccessible locations. All bonds which will be in concealed or inaccessible locations shall be brazed or welded.

3.14.12 Coupling of dissimilar metals. Compression bonding with bolts and clamps shall be used only between metals having acceptable coupling values as shown in Table VI. When the base metals form couples that are not allowed, the metals shall be coated, plated, or otherwise protected with a conductive finish or, a washer made of a material compatible with each shall be inserted between the two base metals. The washer shall be constructed of, or plated with an appropriate intermediate metal as determined from Table VI.

3.14.13 Surface preparation. All mating surfaces which comprise a bond shall be thoroughly cleaned before joining to remove dust, dirt, grease, oil, moisture, non-conductive protective finishes, and corrosion products.

3.14.13.1 Paint removal. Paints, primers, and other non-conductive finishes shall be removed from the metal base with appropriate chemical paint removers, or the surface shall be sanded with 500-grit abrasive paper or equivalent.

3.14.13.2 Inorganic film removal. Rust, oxides, and non-conductive surface finishes (anodized, galvanized, etc.) shall be removed by sand blasting, by using abrasive paper or cloth with 320-grit or finer, or by using an appropriate wire brush technique. Gentle and uniform pressure shall be employed when using abrasive papers or cloths or wire brushes to obtain a smooth, uniform surface. No more metal than necessary to achieve a clean surface shall be removed.

3.14.13.3 Area to be cleaned. All bonding surfaces shall be cleaned over an area that extends at least 1/4 in. (6.4 mm) beyond all sides of the bonded area on the larger member.

3.14.13.4 Final cleaning. After initial cleaning with chemical paint removers or mechanical abrasives, the bare metal shall be wiped or brushed with an appropriate solvent meeting the requirements of P-D-680. Prior to bonding, surfaces not requiring the use of mechanical abrasives or chemical removers shall be cleaned with a dry cleaning solvent to remove grease, oil, corrosion preventives, dust, dirt, and moisture.

3.14.13.4.1 Clad metals. Clad metal shall be carefully cleaned, to a bright, shiny, smooth surface, with fine steel wool or grit so the cladding material is not penetrated by the cleaning process. The cleaned area shall be wiped with dry cleaning solvent and allowed to air dry before completing the bond.

3.14.13.4.2 Aluminum alloys. After cleaning of aluminum surfaces to a bright finish, a brush coating of alodine or other similar conductive finish shall be applied to the mating surfaces.

3.14.13.5 Completion of the bond. If an intentional protective coating is removed from the metal surface, the mating surfaces shall be joined within 4 hours after cleaning.

3.14.13.6 Refinishing of bond. Bonds shall be refinished so as to match the existing finish as close as possible within the requirements of Para. 3.14.14.

3.14.14 Bond protection. All bonds shall be protected against weather, corrosive atmospheres, and mechanical damage. Under dry conditions, a corrosion preventive or sealant shall be applied within 24 hours of assembly of the bond materials. Under conditions exceeding 60% humidity, sealing of the bond shall be accomplished within 1 hour of joining.

3.14.14.1 Paint. If a paint finish is required on the final assembly, the bond shall be sealed with the recommended finish. Care shall be taken to assure that all means by which moisture or other contaminants may enter the bond are sealed. A waterproof type of paint or primer conforming to FAA-STD-012 shall be used if the recommended finish is not waterproof.

3.14.14.2 Inaccessible locations. Bonds which are located in areas not reasonably accessible for maintenance shall be sealed with permanent, waterproof compounds after assembly.

3.14.14.3 Accessible locations. If a paint finish is not required after assembly of the bond, a silicone or petroleum-based sealant shall be applied.

3.14.14.4 Compression bonds in protected areas. Compression bonds between copper conductors or between compatible aluminum alloys located in readily accessible areas not exposed to weather, corrosive fumes, or excessive dust do not require sealing, subject to Contracting Officer approval.

3.15 Shielding requirements

3.15.1 Design. The facility design and construction shall incorporate protective shields to attenuate radiated signals, and separation of equipment and conductors to minimize the coupling of interference.

3.15.2 Facility shielding. The shielding of facility buildings, shelters or equipment spaces shall be provided when other facility or environmental sources of radiation are of sufficient magnitude to degrade the operation and performance of electronic equipment. Unless otherwise specified, the bonding and grounding of metal structural components, building elements and the space separation of equipment and conductors shall be as indicated herein.

3.15.3 Conductor and cable shielding. Conductor and cable shielding shall comply with the following:

3.15.3.1 Signal lines and cables. Cables consisting of multiple twisted pairs shall have the individual shields isolated from each other. Cables with an overall shield shall have the shield insulated.

3.15.3.2 Termination of individual shields. Shields of pairs of conductors and the shield of cables containing unshielded conductors shall be terminated in accordance with the following:

(a) Shields shall be terminated as applicable for equipment operation.

(b) Shield terminations shall employ minimum length pigtails between the shield and the connection to the bonding halo or ferrule ring, and between the halo or ferrule ring and the shield pin on the connector. The unshielded length of a signal line shall not exceed 1 in. (25 mm) with not more than 1/2 in. (13 mm) of exposed length as the desired goal.

(c) Shields, individually and collectively, shall be isolated from overall shields of cable bundles and from electronic equipment cases, racks, cabinet, junction boxes, conduit, cable trays, and elements of the electronic multipoint ground system. Except for one interconnection, individual shields shall be isolated from each other. This isolation shall be maintained in junction boxes, patch panels and distribution boxes throughout the cable run. When a signal line is interrupted such as in a junction box, the shield shall be carried through. The length of unshielded conductors shall not exceed 1 in. (25 mm). To meet this requirement, the length of shield pigtail may be longer than 1 in. but shall be the minimum required.

(d) Nothing in this requirement shall preclude the extension of the shields through the connector or past the terminal strip to individual circuits or chassis if required to minimize unwanted coupling inside the electronic equipment. Where extensions of this type are necessary, overall cable or bundle shields grounded in accordance with Para. 3.15.3.3 shall be provided.

3.15.3.3 Termination of overall shields. Cables that have an overall shield over individually shielded pairs shall have the overall shield grounded at each end and at intermediate points in accordance with the following.
(a) Cable shields terminated to connectors shall be bonded to the connector shell as shown in Figure 7, Grounding of Overall Cable Shields to Connectors and Penetrated Walls, a), Box Connector, or b), Grounding of Multi-Pin Connector. The shield shall be carefully cleaned to remove dirt, moisture, and corrosion products. The connector securing clamp shall be carefully tightened to assure that a low resistance bond to the connector shell is achieved completely around the circumference of the cable shield. The bond shall be protected against corrosion in accordance with Para. 3.14.14.

(b) Where the cable continuity is interrupted such as in a junction box, the shield shall be carried through and grounded at the box. The length of unshielded conductors shall not exceed 1 in. (25 mm). To meet this requirement the length of shield pigtail may be longer than 1 in., if necessary, to reach ground but shall be kept to a minimum.

(c) Cables which penetrate walls or panels of cases or enclosures without the use of connectors shall have their shields bonded to the penetrated surface in the manner shown in Figure 7 c), Partition Penetration. Overall shields shall be terminated to the outer surface of cases to the maximum extent possible.

(d) Grounding of overall shields to terminal strips shall be as shown in Figure 8, Grounding Overall Shield to Terminal Strip.

3.15.4 Space separation. The design and layout of facilities shall physically separate electronic equipment and conductors which produce interference from equipment and conductors that are susceptible to interference. In general, electronic equipment and conductors which carry, produce or use high levels of current (greater than 100 ma) or voltage (12V or more), including pulse power, can produce interference. Electronic equipment and conductors which carry, produce or receive low voltage or power levels are susceptible to interference.

3.16 Control of static electricity

3.16.1 General. Modern electronic equipment with high speed and miniaturized circuitry is highly susceptible to damage by electrostatic discharge (ESD). The requirements of this paragraph are designed to minimize this occurrence and shall be used in addition to NFPA 77.

3.16.2 Controlled areas. Operation, storage, repair and maintenance spaces used for circuits and electronic equipment subject to damage by static electricity shall be designated as ESD controlled areas.

3.16.3 Humidity control. The relative humidity in ESD controlled areas shall be maintained in the 40-60% range as feasible for new construction and renovated spaces. Humidification must be analyzed in conjunction with heating and cooling requirements since it is affected by these characteristics. Outside walls, roof ceilings, and grade level floors shall have continuous plastic, aluminum foil or sheet metal incorporated in their construction to limit moisture migration. Foil or sheet metal is preferred for walls and ceilings because of their shielding and ground plane properties. Where plastics are used, they shall be of a type which dissipates electric charge. The effect of joints shall be minimized by overlapping plastic and metal sheet materials, by interlocking and conductive caulking sheet metal or panel joints, and by metallic tape for aluminum foil backed materials. Where shielding is required, it shall be incorporated as required in Para. 3.15 through 3.15.5.

3.16.4 Work surfaces. Test, repair and maintenance stations and other work surfaces and their associated standing space shall be covered with a conducting material designed to protect components and assemblies from ESD. A small ground plate, connected to the electronic multipoint ground system, shall also be provided for the positive discharge of personnel, tools and test leads prior to direct contact with components and assemblies.

3.16.5 Tools and accessories. All tools and work bench accessories shall be selected to minimize discharge and damage to components and assemblies.

3.16.6 Furniture and upholstery. All upholstery and chair covering material in controlled spaces shall have a low propensity to store static electricity. Chairs and upholstered furniture shall have metal frames. Stationary feet shall be conductive (uninsulated). Casters and rollers on chairs and movable furniture shall be steel, conductive rubber or conductive plastic.

3.16.7 Floors. Floors of all rooms containing electronic equipment shall have a static dissipating surface and shall be connected to the electronic multipoint ground system. This may be raised flooring, carpet or linoleum type material and shall be of such design as to ensure electrical continuity. Where raised floors use acoustical isolation strips under the removable floor tiles, the strips shall be made of conductive rubber or plastic. In addition metal grounding clips shall be provided at each stanchion or pedestal to assure that charges are drained. Materials used for static dissipating surfaces shall meet the requirements of UL 779 (also listed as ANSI-A148.1).

3.16.8 Ion generation. High-voltage ionization generators may be used in small spaces when cost effective in comparison with other static electricity control measures. These shall be of a type which produces both positive and negative ions.

4. QUALITY ASSURANCE PROVISIONS

4.1 Test Plan. Contractors shall develop a test plan in accordance with MIL-HDBK-237 to demonstrate compliance with the requirements of this standard where applicable.

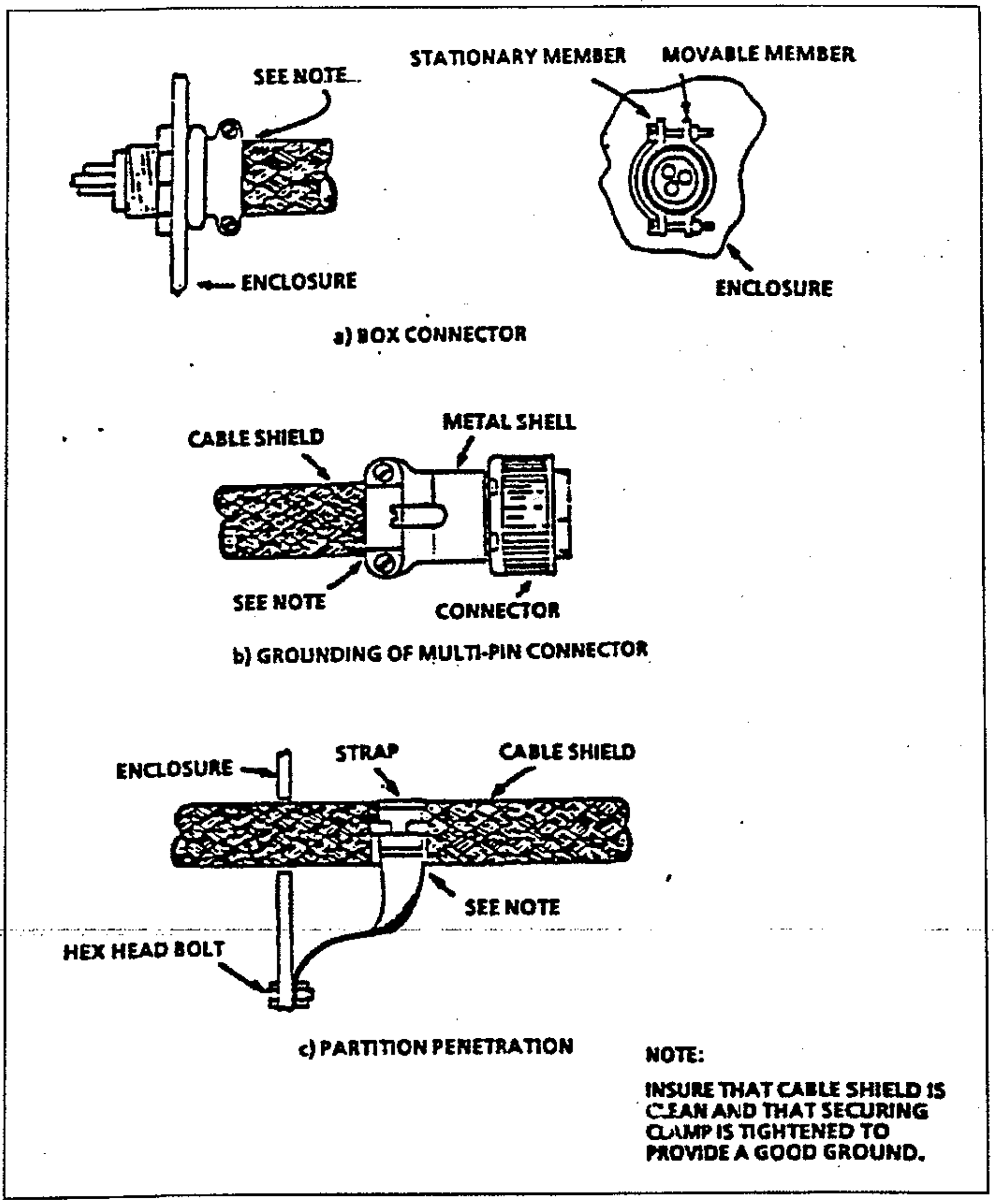


Figure 7 Grounding of Overall Cable Shields to Connectors and Penetrated Walls.

4.2 Approval. Test plans shall be submitted for Contracting Officer approval.

5. PREPARATION FOR DELIVERY. Section is not applicable to this standard.

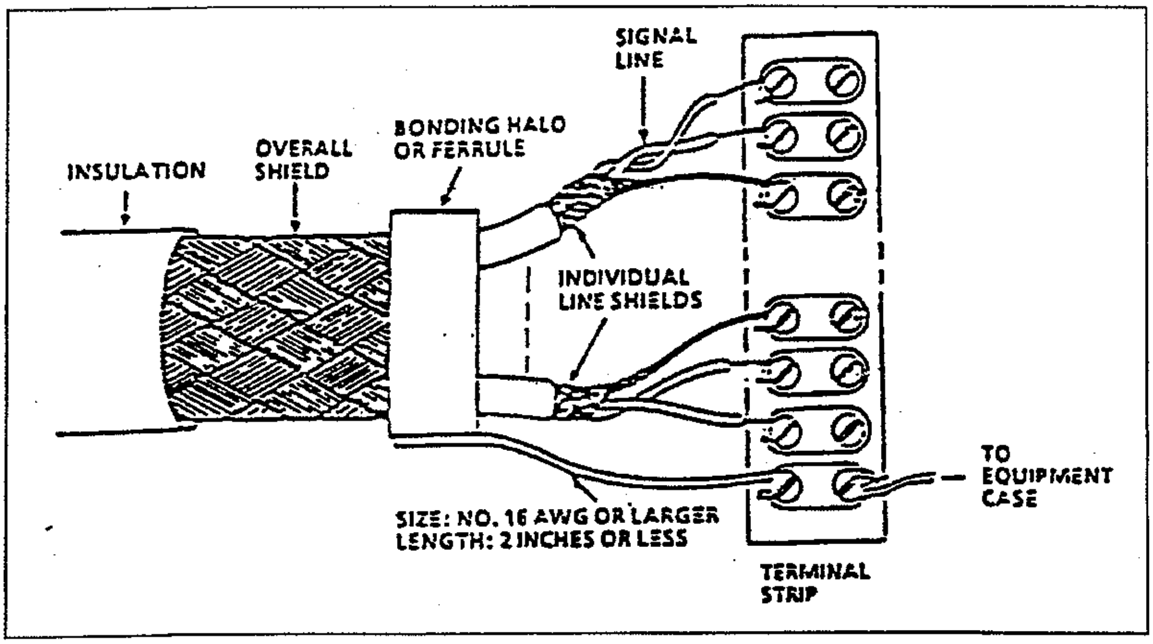


Figure 8 Grounding Overall Shield to Terminal Strip

6. NOTES

6.1 Definitions

6.1.1 Access well. A small covered opening in the earth using concrete, clay pipe or other wall material to provide access to an earth electrode system connection.

6.1.2 Air terminal. A metallic rod mounted on a building or structure specifically designed to intercept lightning strikes.

6.1.3 Arrester. Components, devices or circuits used to attenuate, suppress or divert excess electrical (surge and transient) energy to ground. The terms arrester, suppressor and protector are used interchangeably except that the term arrester is used herein for components, devices and circuits at the service disconnecting means.

6.1.4 Bond. The electrical connection between two metallic surfaces used to provide a low resistance path between them.

6.1.5 Bond, direct. An electrical connection utilizing continuous metal-to-metal contact between the members being joined.

6.1.6 Bond, indirect. An electrical connection employing an intermediate electrical conductor between the bonded members.

6.1.7 Bonding. The joining of metallic parts to form an electrically conductive path to assure electrical continuity and the capacity to conduct current imposed between the metallic parts.

6.1.8 Bonding jumper. A conductor to assure electrical conductivity between metal parts required to be electrically connected.

6.1.9 Branch circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

6.1.10 Brazing. A joining process using a filler metal with working temperature above 800F but below the melting point of the base metal(s).

6.1.11 Building. The fixed or transportable structure which provides environmental protection.

6.1.12 Cabinet. A protective housing or covering for two or more units or pieces of equipment. A cabinet may consist of an enclosed rack with hinged doors.

6.1.13 Case. A protective housing for a unit or piece of electrical or electronic equipment.

6.1.14 Chassis. The metal structure that supports the electrical or electronic components which make up the unit or system.

6.1.15 Clamp voltage. The voltage that appears across transient suppressor terminals when the suppressor is conducting transient current.

6.1.16 Conductor. Bare or insulated, see below.

6.1.16.1 Conductor, bare. A conductor having no covering or electrical insulation.

6.1.16.2 Conductor, insulated. A conductor encased within material of composition and thickness recognized by the NEC as electrical insulation.

6.1.16.3 Conductor, lightning bonding (secondary). A conductor used to bond a metal object, within the zone of protection and subject to potential build-up different from the lightning current, to the lightning protection system.

6.1.16.4 Conductor, lightning down. The down conductor that serves as the path to the earth grounding system from the roof system of air terminals and roof conductors or from an overhead ground wire.

6.1.16.5 Conductor, lightning main. The main conductors are the conductors of the lightning protection system. These can be the roof conductors interconnecting the air terminals on the roof, the conductor to connect a metal object on or above roof level that is subject to a direct lightning strike to the lightning protection system, or the down conductor.

6.1.16.6 Conductor, lightning roof. Roof conductors interconnecting all air terminals to form a two-way path to ground from the base of each air terminal.

6.1.17 Crowbar. Crowbar is a method of shorting a surge current to ground in surge protection devices. This method provides protection against more massive surges than other types, but lowers the clamping voltage below the operational voltage of the electronic equipment causing noise and operational problems. It also permits a follow current which can cause damage.

6.1.18 Earth electrode system (grounding electrode system). A network of electrically interconnected rods, plates, mats, piping, incidental electrodes (metallic tanks, etc.) or grids installed below grade to establish a low resistance contact with earth.

6.1.19 Electromagnetic interference. Any emitted, radiated, conducted or induced voltage which degrades, obstructs, or interrupts the desired performance of electronic equipment.

6.1.20 Electronic multipoint ground system. An electrically continuous network consisting of interconnected ground plates, equipment racks, cabinets, conduit, junction boxes, raceways, duct work, pipes and other normally non-current-carrying metal elements for electronic signals. It includes conductors, jumpers and straps that connect individual electronic equipment components to the electronic multipoint ground system.

6.1.21 Electronic single point ground system. A single point ground system provides a single point reference in the facility for electronic signals. The single point ground system shall be installed in a trunk and branch arrangement to prevent conductive loops in the system. It shall be isolated from all other ground systems except for an interconnection, where applicable, to the multipoint ground system at the main ground plate. The single point ground system consists of insulated conductors, copper ground plates mounted on insulated stands, and insulated ground plates, buses, and/or signal ground terminals in the electronic equipment which are isolated from the frame of the equipment.

6.1.22 Equipment grounding conductor. The conductor used to connect non-current-carrying metal parts of equipment, raceways, or other enclosures to the system grounded conductor and/or grounding electrode conductor at the service entrance or at the source of a separately derived system.

6.1.23 Equipment, unit or piece of. An item having a complete function apart from being a component of a system.

6.1.24 Feeder. All circuit conductors between the service equipment or the source of a separately derived system and the final branch circuit overcurrent device.

6.1.25 Facility ground system. Consists of the complete ground system at a facility including the earth electrode system, electronic multipoint ground system, electronic single point ground system, equipment grounding conductors, grounding electrode conductor(s), and lightning protection system.

6.1.26 Fitting, high compression. See "Pressure Connector."

6.1.27 Ground. A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

6.1.28 Grounded. Connected to earth or to some conducting body that serves in place of the earth.

6.1.29 Grounded conductor. A system or circuit conductor that is intentionally grounded at the service disconnecting means and at the transformer serving the facility. This grounded conductor is the neutral conductor for the power system.

6.1.30 Grounded, effectively. Permanently connected to earth through a ground connection of sufficiently low impedance and having sufficient current carrying capacity that ground fault current which may occur cannot cause a voltage build up dangerous to personnel.

6.1.31 Grounding conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a reference ground system.

6.1.32 Grounding electrode. Copper rod, plate or wire embedded in the ground for the specific purpose of dissipating electric energy to the earth.

6.1.33 Grounding electrode conductor. The conductor used to connect the grounding electrode to the equipment grounding conductor and/or to the grounded (neutral) conductor of the facility at the service disconnecting means or at the source of a separately derived system.

6.1.34 High frequency. All electrical signals at frequencies greater than 100 kilohertz (kHz). Pulse and digital signals with rise and fall times of less than 10 microseconds are classified as high frequency signals.

6.1.35 Landline. Any conductor, line or cable installed externally above or below grade to interconnect electronic equipment in different facility structures or to connect externally mounted electronic equipment.

6.1.36 Line replaceable unit. Hardware elements whose design enables removal, replacement and checkout by organizational maintenance.

6.1.37 Low frequency. Includes all voltages and currents, whether signals, control, or power, from DC through 100 kHz. Pulse and digital signals with rise times of 10 s or greater are considered low frequency signals.

6.1.38 Overshoot voltage. The fast rising voltage that appears across transient suppressor terminals before the suppressor turns on (conducts current) and clamps the input voltage to a specified level.

6.1.39 Pressure connector. For purpose of this document, "FAA approved pressure connectors" shall be those which use hydraulic crimpers or an explosive charge to effect closure.

6.1.40 Rack. A frame in which one or more equipment units are mounted.

6.1.41 Reference plane or point, electronic signal. The conductive terminal, wire, bus, plane, or network which serves as the ground reference for all signals referenced thereto.

6.1.42 Reverse standoff voltage. The maximum voltage that can be applied across transient suppressor terminals with the transient suppressor remaining in a non-conducting state.

6.1.43 Shield. A housing, screen, or cover which substantially reduces the coupling of electric and magnetic fields into or out of circuits or prevents accidental contact of objects or persons with parts or components operating at hazardous voltage levels.

6.1.44 Structure. Any fixed or transportable building, shelter, tower, or mast that is intended to house electrical or electronic equipment or otherwise support or function as an integral element of the air traffic control system.

6.1.45 Transient suppressor. Component(s), device(s) or circuit designed to attenuate, suppress or divert conducted transient(s) and surge energy to ground to protect electronic equipment.

6.1.46 Turnon voltage. The voltage required across a transient suppressor terminal to cause the suppressor to conduct current.

6.2 Acronyms and abbreviations. The following are acronyms and abbreviations used in this standard.

A	-	amperes	LRU	-	line replaceable unit
AC	-	alternating current	m	-	meter
AWG	-	American wire gauge	ma	-	milliamperes
cm	-	centimeter(s)	MCM	-	thousand circular mils
cmil	-	circular mils	MHz	-	megahertz
DC	-	direct current	mm	-	millimeter(s)
e.g.	-	for example	NEC	-	National Electric Code
ESD	-	electrostatic discharge	NEMA	-	National Electrical Manufacturers Association
Et.al.	-	and others	NFPA	-	National Fire Protection Assn.
FAA	-	Federal Aviation Admin	Para.	-	paragraph
ft.	-	foot (feet)	PVC	-	polyvinyl chloride
Hz	-	hertz	RF	-	radio frequency
i.e.	-	that is	SAS	-	silicon avalanche suppressors
in.	-	inch(es)	UL	-	Underwriters' Laboratories
kA	-	kiloampere	μs	-	microseconds
kg	-	kilogram	V	-	volts
kHz	-	kilohertz			

APPENDIX 3

USDOT/FAA Order 6950.2D

Electrical Power Implementation at National Airspace System Facilies

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ORDER

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

6950.2D

10/1/98

SUBJ: ELECTRICAL POWER POLICY IMPLEMENTATION AT NATIONAL AIRSPACE SYSTEM FACILITIES.

1. PURPOSE. This order provides guidance for electrical power policy implementation at the National Airspace System Facilities (NAS) in accordance with the latest version of Order 6030.20, Electrical Power Policy. This order identifies standard electrical power configurations to ensure NAS facility availability commensurate with its assigned mission.

2. DISTRIBUTION. This order is distributed to the division level in the Airway Facilities; Office of Communication, Navigation, and Surveillance Systems; Office of System Architecture and Investment Analysis; and Office of Acquisitions in Washington; to division level in the FAA Logistics Center and the FAA Academy at the Aeronautical Center; to the division level in the Office of Communication, Navigation, and Surveillance Engineering and Test Division at the Technical Center; to the branch level in the regional Airway Facilities divisions; and to all Airway Facilities field offices with a standard distribution.

3. CANCELLATION. Order 6950.2C, Electrical Power Policy Implementation at National Airspace System Facilities, dated November 16, 1987, is canceled.

4. BACKGROUND. The modernization of the NAS and revisions to the Electrical Power Policy created the need to revise this implementation order.

5. EXPLANATION OF CHANGES.

a. Extensive revisions to this order have been performed to comply with Public Law 104-113, H.R. 2196, the National Technology Transfer and Advancement Act of 1996, and to modernize outdated requirements contained in the existing order.

b. Specific changes have been made to incorporate sensitive electronic power requirements, especially in the power quality area. Appendix 1, Facility Power Source Codes, has been revised to reflect the current facility types. Also, appendix 1 has been divided into two sections - Part A - General National Airspace System (GNAS) and Part B - Air Route Traffic Control Center (ARTCC). Appendix 2, Current Distortion Guidelines, has been added to provide guidance for individual system/equipment harmonic assessment. Appendix 3, Power Criteria, has been added to give a description of the general power quality to be provided to mission related electronic equipment.

Distribution: A-W(AF/ND/SD/SU)-3; A-X(AF)-3; A-Y(ML/MA)-2; A-Z(ACT-300,3 Copies); A-FAF-0 (STD)

Initiated By: ANS-600

6. APPLICATION. This order applies to all Federal Aviation Administration (FAA) NAS facilities without regard to maintenance and operational responsibility. The guidance and electrical power configurations identified by this order shall be used by the responsible organizations in establishing configuration requirements for FAA and non-FAA owned facilities. Those facilities solely for military or private use are exempted from this order. Standby power requirements for non-FAA airport lighting systems are identified in Advisory Circular 150/5340-17B, Standby Power for Non-FAA Airport Lighting Systems.

7. RESPONSIBILITIES.

a. NAS Transition and Integration (ANS) will issue technical standards and guidance to implement the power configurations necessary to meet requirements of this order and Order 6030.20.

b. Regional Airway Facilities divisions shall periodically review the performance of facility power systems and recommend changes consistent with operational requirements.

c. The appropriate program office or Integrated Product Team shall identify and budget for the power requirements of new facility types during the development process. The NAS Infrastructure Power Systems (NIPS) Product Team shall identify and budget for sustained power support programs required by the latest version of Federal Aviation Administration Acquisition Management System (AMS).

8. GENERAL GUIDANCE.

a. For definitions of facility types and services and facility contractions listed in appendix 1, of this order, use the latest version of Order 6000.5, Facility, Service, and Equipment Profile. Where contractions are not contained in Order 6000.5, they will be identified in the latest version of Order 1380.40, Airway Facilities Sector Level Staffing Standard System, Appendix 1, Facility Types, Contractions, and Definitions and the latest version of Order 1375.4, Standard Data Elements and Codes - Facility Identification and Supplemental Standards.

b. Appendix 1, of this order, identifies the standard power configuration which is effective upon issuance of the order. In many cases these standards will differ from present facility installations due to facility and equipment replacement programs or changes to operational service requirements. Changes to standard configurations in this order do not in themselves provide authority or desirability for change from the present configuration. Transition to new standards shall be accomplished under approved projects through normal budgetary actions. Deviations from the configurations in appendix 1 of this order or changes to baseline configurations shall be requested through the NAS Change Proposal (NCP) process in accordance with the latest version of Order 1800.8, National Airspace System Configuration Management, for all new facility or equipment installations. NCPs are not required for present installations which deviate from these standard configurations provided they are in conformance with prior standards and meet the operational requirements of the facility.

c. The Power Source Codes listed in appendix 1, of this order, are defined in Order 6000.5, Appendix 3, Special Use Facilities Master File Reporting Codes, and are further described as follows:

(1) A - denotes a commercial power source, a standby engine generator and an Uninterruptible Power Supply (UPS). This configuration shall provide uninterruptible, conditioned power with AC voltage in and AC voltage out.

(2) D - denotes a commercial power source and a battery standby power system. A UPS is not included in this category.

(3) V - denotes a photovoltaic or wind generator with a battery system.

(4) Z - denotes a single source of power continuously generated by an independent generating device; e.g., thermoelectric, prime power engine generator, nuclear, fuel cell, etc.

(5) 1 - denotes a commercial power source and a standby engine generator.

(6) 4 - denotes a single source of power.

(7) 8 - denotes dual, independent sources of commercial power; i.e., two separate substations.

d. For an airport identified as a Continuous Power Airport (CPA), as defined in Order 6030.20, only the facilities associated with the operation of the one designated CPA runway shall be configured with CPA facility power service levels indicated in appendix 1 of this order.

e. Where specified, power equipment used for support of Category II and III operations shall be capable of transferring to an alternate source within 1 second. The 1-second transfer time can be obtained by powering the facility with the engine generator during the Category II or III conditions and using commercial power as the standby source. Should the engine generator fail, the facility load will automatically transfer back to commercial power within the required 1-second transfer time. Once the Category II or III conditions have subsided, the facility shall be returned to the commercial (primary) power source.

f. Appendix 1, of this order, indicates the standard power service for each facility type. In some instances, an alternate configuration may satisfy facility requirements more cost-effectively. Requests for the following alternate configurations shall be accomplished through the NCP process:

(1) Power Source Code V may be used in place of Codes 4, 1, and D where reliability and life cycle cost considerations are favorable compared with engine generator systems or the installation and costs of primary commercial power. Battery reserve power for these systems should be sized for a minimum of 4 hours service based on the worst case environmental conditions for the particular facility location.

(2) Power Source Code Z may be used in place of Code 4 where reliability and life cycle cost considerations are favorable compared with the installation and costs of primary commercial power.

(3) Power Source Code D should be used in lieu of Code 1 when equipment upgrade allows facility's operational requirements to be satisfied by a battery standby power system.

g. Facilities with standby power systems, capable of being remotely monitored, should monitor the status of commercial power and standby power systems.

h. FAA facilities with standby power systems authorized by appendix 1, of this order, which are owned and operated by a non-FAA authority, must meet the requirements of the latest version of Order 6950.11, Reduce Electrical Power Interruptions at FAA Facilities.

9. TECHNICAL GUIDANCE.

a. Electrical power characteristics of the power provided to electronics equipment shall meet the conditions defined in appendix 3 of this order. Should the electrical power characteristics deviate from appendix 3 requirements, refer to the latest version of Order 6950.25, Use of Electrical Power Conditioning Devices at FAA Facilities, for corrective actions.

b. The quality of electrical power provided shall be of the reliability, availability, and voltage and frequency standards required for the facility. VOLTAGE Total Harmonic Distortion (THD) shall not exceed 5% THD or 3% HD for any single harmonic. These limits shall apply at the service entrance only. These limits are goals at all other facility voltage bus locations. Distortion exceeding these limits, including at the engine generator output, should be evaluated by personnel, who are competent in the technical power quality discipline, for adverse impact to equipment and power distribution system. For CURRENT distortion considerations, refer to paragraph 9j(5).

c. Specific requirements for various power services are as follows:

(1) Facilities which utilize a standby engine generator, Power Source Code 1, shall provide standby power within 15 seconds of a failure of the prime power source and shall be capable of sustained operation. ARTCC facilities using Power Source Code 1, will be provided standby power service as defined in the latest version of Order 6470.5, Maintenance of ARTCCs.

(a) In general, a 72 hour fuel supply shall be maintained. A reduced fuel supply may be maintained at locations where fuel is readily available and delivery agreements are in place; e.g., major airports and where fuel volume is continuously monitored. At facilities with difficult access, fuel supplies shall be determined on a site-by-site basis. In all cases, fuel supplies shall be based on actual engine generator loading, not on maximum engine fuel consumption rates.

(b) Facilities with pipeline-fed standby engine generators do not require stored fuel supplies, with the exception of facilities located in areas subject to pipeline failures. At these locations, fuel supplies shall be established on a site-by-site basis.

(c) Closed transition switching; e.g., Uninterruptible Power Transfer (UPT), shall be installed where justified by operational requirements, after coordination with the electric utility.

(2) Facilities which utilize a battery standby power system, Power Source Code D, shall provide standby power immediately (without interruption) upon failure of the prime power source and shall be capable of sustained operation for a minimum of 4 hours at the lowest normal operating temperature of the facility, usually the inside ambient temperature.

(a) A permanently wired means of connection with an appropriate transfer switch may be provided to permit a safe and accurate means to connect and disconnect an external generator to the facility's electrical system to permit recharge of the batteries in the event of a prolonged prime power outage.

(b) The battery system outputs shall be in multiples of 12 volts; e.g., 12, 24, 36, 48 volts and be sized for the systems served.

d. Facilities which utilize a dual source (Power Source Code 8) shall provide transfer from source to source within a maximum of 15 seconds.

e. Site generated power systems (Power Source Code V and Z) shall be established to provide continuous power without required on-site maintenance activity more frequent than the normal facility preventive maintenance schedule.

f. Agency owned prime engine generator power systems shall only be utilized where no other source of power is available or where the expense of other sources of power would exceed that of establishing and operating such a system. The system shall consist of at least two engine generators specifically designed for continuous operations, and shall have either automatic transfer switches designed in accordance with agency standards or 24-hour attendance.

g. Where system/equipments or subsidiary components are co-located at a facility or shelter and different power configurations are required by appendix 1, of this order, or where "same as host facility" appears in appendix 1, the following criteria shall be used, provided that power quality, capacity, and availability are not degraded:

(1) Where engine generator standby power is available, equipment, systems and components may be configured to Power Source Code 1. Standby battery systems connected to engine generators are not required to have the minimum 4-hour battery reserve.

(2) At facilities where batteries are the primary source of standby power, new equipment that has requirements for standby power may be reconfigured to Power Source Code D.

(3) At facilities with Power Source Code A, only systems/equipments designated as Power Source Code A in appendix 1, of this order, shall be allowed on the output of the facility UPS.

h. Power distribution systems shall be in accordance with FAA orders and specifications and with applicable national and local codes.

i. Power conditioning devices, not addressed by the power source codes in appendix 1, of this order, may be required at some facilities to provide a stable regulated power source. Each installation shall be separately justified, in accordance with the requirements of Order 6950.25. Prior to the installation of a power conditioning device to power specific loads in an existing facility, the following analyses shall be obtained:

(1) An analysis of the existing electronic equipment load characteristics to establish power consumption, current harmonics, inrush current profile, power factor, etc.

(2) An analysis to insure compatibility between the equipment load analysis obtained and the proposed power conditioning device.

(3) An analysis of the impact of the proposed power conditioning device on its source and the rest of the facility; e.g., voltage regulation, harmonic distortion, inrush currents and transient generation, resulting from powering the equipment load.

(4) On a study conducted in accordance with the latest version of Order 6950.27, Short Circuit Analysis and Protective Device Coordination Study (SCA/PDC).

(5) An analysis of the potential to introduce or worsen a "single point of failure" and the subsequent impact to the NAS.

j. Before connecting any equipment to a power bus/system, the following criteria must be satisfied:

(1) The equipment shall be operated and maintained in accordance with established FAA practices. For leased equipment that will be operated or maintained by a contractor, the contract shall require the equipment to be operated and maintained in accordance with FAA practices. Maintenance records and equipment shall be available at each leased equipment location for review and technical evaluation by designated FAA personnel. Equipment shall be tested until the FAA is assured it is compatible with the system from which it will be powered. Testing shall not be performed on a critical power system or on the output of a Power Source Code A system, unless there is an UPS specifically provided for testing purposes. All testing shall be completed and approved prior to the equipment being connected in an operational environment. At no time shall any equipment be connected to an existing facility's power system if it adversely affects the operation or performance of other equipment.

(2) The power required by the equipment must be analyzed to insure that the facility power system does not become overloaded or unbalanced.

(3) Peak inrush current and current THD of electronic equipment shall not exceed the limits specified in Specification FAA-G-2100, Electronic Equipment, General Requirements. All other loads shall have a peak inrush current characteristic that will not cause power anomalies detrimental to the facility operation, nuisance over-current device operation, or operational problems with the source.

(4) Power factor at the service entrance shall be within 0.8 lagging to 1.0 or as required by the local utility contract. Power factor at the engine generator output shall be 0.8 lagging to 1.0. Power factor at all other locations shall be considered with regard to energy conservation and performance of power sources and power conditioners. The total power factor is the product of the displacement power factor and the distortion power factor, $PF_{TOT} = (PF_{disp})(PF_{dist})$.

(5) The impact to the bus of the CURRENT THD of each electronic equipment/ system and environmental equipment/system (such as air conditioners, lighting, UPS, etc.) shall be considered when connecting to a bus. The curve in the graph, Current Distortion as a Function of System Load, in appendix 2 shall be used as a guideline to indicate when current distortion mitigation may be necessary to prevent the connection of high harmonic generative loads that will affect the VOLTAGE THD and thus, the power budget of the facility. When the distortion exceeds the curve for the specific load, an evaluation/analysis shall be performed by personnel, who are competent in the technical power quality discipline, to insure that there are no adverse impacts to equipment operation or the power distribution system.

10. SPECIAL CONSIDERATIONS. At some facilities, special situations may dictate a power configuration different from that described in paragraph 8 and assigned in appendix 1. Some of the special situations are discussed below:

a. **Meteorological.** A facility located in an area with a history of electrical, ice, or wind storms, which have caused abnormally frequent prime power disruptions and/or excessively long outages, may qualify for a higher grade power configuration if such disruptions cannot be tolerated.

b. **Accessibility.** A facility located in a remote area where a prime power outage is likely to be of a duration incompatible with operating requirements, and could result in excessive exposure of maintenance personnel to hazards, may qualify for a higher grade power configuration.

c. **Defense Readiness.** In some cases, the requirement to maintain an effective defense readiness posture differs from the normal operational requirement.

d. **Military Requirements.** A higher grade power configuration may be necessary due to specific military requirements.

e. Power Quality. A facility located in an area of poor utility power quality, that would adversely affect facility operation.

11. IMPLEMENTATION. All commissioned facilities shall be provided with power that is within the prescribed limits established by the facility standards and this order.

a. New installations shall be configured in accordance with this order.

b. An exception to the standard configuration identified by facility standards and this order shall be separately justified in accordance with paragraph 8b when a retention, establishment, modification or improvement project is proposed.

c. Changes to the power system or the installation of new equipment requires the accomplishment or update of short circuit analysis and protective device coordination studies in accordance with FAA-STD-032, Design Standards for National Airspace System Physical Facilities, and Order 6950.27.

Stanley Rivers
Director of Airway Facilities

APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
AFSS	Automated Flight Service Station	1	
ALS	Approach Lighting System	4 (CAT I) 1 (CAT II/III) 1 (CPA)	CAT II/III requires 1 sec. transfer
ARMS	Airport Remote Monitoring System	D	
ARSR	Air Route Surveillance Radar	1	
ARTS - II	Automated Radar Terminal System	1	
ARTS - III	Automated Radar Terminal System	A	
ASDE	Airport Surface Detection Equipment	A	Includes Antenna, but not heater
ASI	Altimeter Setting Indicator		same as host facility
ASOS	Automated Surface Observation System	4	
ASR	Airport Surveillance Radar	1	
ATCBI	Air Traffic Control Beacon Interrogator	1	
ATCRB	Air Traffic Control Radar Beacon	1	
ATCT (As defined by Order 6480.7)	Airport Traffic Control Tower	4 (Low and Intermediate activity with non-radar approach control) 1 (Low and intermediate activity with radar approach control, major activity)	"critical services" (per Order **6480.7)=D**. "critical services" (per Order **6480.7)=1**
ATIS	Automatic Terminal Information System		same as host facility
AWANS	Aviation Weather and **NOTAM** System	4	

<u>Power Source Code Definitions</u>:
A = Commercial Power + Engine Generator + UPS
D = Commercial Power + Batteries
V = Photovoltaic/Wind Generator + Battery
Z = Independent Generation
1 = Commercial Power + Engine Generator
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8 = Dual Independent Commercial Power

APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS (CONTINUED)

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
AWIS	Airport Weather and Information System		same as host facility
AWOS	Automated Weather Observation System	4	
BDIS - Class A	Automatic Interchange Service B - Solid State	A	
BRITE	Brite Radar Indicator Terminal Equipment		same as host facility
BUEC	Back-up Emergency Communications	D	
CCMS	Central Control Monitoring System	A	"CPU only"
CCTV	Closed Circuit TV	4	
CD	Common Digitizer	1	
CERAP	Combined Center/Rapcon	1	
CFCC	Central Flow Control Computer	A	
CMLT	Communication Microwave Link Terminal	1	
COMCO	Command Communication Outlet	1	
DASI	Digital Altimeter Setting Indicator		same as host facility
DF	Direction Finder	4	
DFI	Direction Finder Indicator		same as host facility
DME	Distance Measuring Equipment		same as host facility
DMUX	Data Multiplex		same as host facility
EARTS	En Route Automated Radar Tracking System	A	
EOF	Emergency Operation Facility	1	
ERMS	Environmental Remote Monitoring System	TBD	

Power Source Code Definitions:
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APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS (CONTINUED)

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
ETVS	Enhanced Terminal Voice Switching	TBD	
FCPU	Facility Central Processor Unit		same as host facility
FDEP	Flight Data Entry and Printout Equipment		same as host facility
FDIOR	Flight Data Input/Output Remote		same as host facility
FFM	ILS Far Field Monitor	D	
FLP	Field Lighting Panel		same as host facility
FM	Fan Marker	D	
FOTS	Fiber Optic Transmission System		same as host facility
FSDPS	Flight Service Data Processing System	A	
FSS	Flight Service Station	4	
GATR	Ground/Air Transmitter/Receiver	D	
GDL	Guidance Light Facility	4	
GMMS	GNAS Maintenance Control Center	1	
GOES	Geostationary Operational Environmental Satellite System		same as host facility
GS	Glide Slope	I	same as LOC
GWDS	Graphics Weather Display System		same as host facility
HCVR	High Capacity Voice Recorder	A	
ICSS	Integrated Communications Switching System	A (AFSS, TRACONS With ARTS III) Other	 same as host facility
IM	Inner Marker	D	
LCOT	UHF/VHF Link Terminal	4	

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APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS (CONTINUED)

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
LDA	Localizer Directional Aid	D	
LDIN	Lead in Light Facility	4	
LFDS	Large Facility Demarcation System	A	same as host facility
LINCS	Leased Interfacility NAS Communications System		same as host facility
LLWAS	Low-Level Wind Shear Alert System	D (sensor) Central/Display Equipment	same are host facility
LMM	Compass Locator at the ILS Middle Marker	D	
LNKR	Link Repeater	4	
LOC	Localizer	D 1 (CPA)	
LOM	Compass Locator at the ILS Outer Marker	D	
LRNCM	Long Range Navigation C Monitor		same as host facility
MALS; MALSR	Medium Intensity Approach Lighting System; Medium Intensity ALS (MALS) with Runway Alignment Indicator Lights	4 (CAT I) 1 (CPA)	
MAPS	Meteorological and Aeronautical Presentation System	4	
MCC	Maintenance Control Center	1	
MCR	Multichannel Recorder		same as host facility
MLS	Microwave Landing System	D	
MM	Middle Marker	D	
Mode S	Mode Select Beacon System	1	
MTI Reflector	Moving Target Indicator - Reflector	V	

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APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS (CONTINUED)

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
NDB	Non-Directional Beacon	4	
NRCS (NARACS)	National Radio Communications System	1 (National Emergency Operating Facilities)	
NXRAD (NEXRAD)	Next Generation Weather Radar	1	
OASIS	Operational And Supportability Implementation System	TBD	
OCC	Operational Control Center	**TBD**	
ODALS	Omnidirectional Airport Lighting System	4	
OM	Outer Marker	D	
PAPI	Precision Approach Path Indicator	4	
PRM	Precision Runway Monitor	1	
RBC	Rotating Beam Ceilometer	4	
RCAG	Remote Center Air/Ground	D 1 with AC Linear Power Amplifier (LPA)	
RCE	Radio Control Equipment		same as host facility
RCIU	Remote Control Interface Unit		same as host facility
RCLR	Radio Communications Link Repeater	D (Single Path) 1 (Dual/Triple Path)	
RCLT	Radio Communications Link Terminal		same as host facility
RCO	Remote Communications Outlet	4	
RDVS	Rapid Deployment Voice Switch		same as host facility

Power Source Code Definitions:
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APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS (CONTINUE@

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
REIL	Runway End Indentification Lights	4	
RMCC	Remote Monitor Control Center		same as host facility
RMCF	Remote Monitor Control Facility		same as host facility
RMLR	Radar Microwave Link Repeater	1 (single Long Range (LRR) Path) A (dual/triple LRR path)	
RMLT	Radar Microwave Link Terminal		same as host facility
RMVC	Remote Maintenance VORTAC Concentrator		same as host facility
RRH	Remote Readout Hygrothermometers	4	
RRCS	Remote Radio Control System		same as host facility
RTR	Remote Transmitter/Receiver	D	
RVR	Runway Visual Range	4 (CAT I) 1 (CAT II (TD)) 1 (CAT III) (TD, MP, RO) 1 (CPA (TD)) D (Type 347AH (TD,MP,RO))	 RO, MP = 4 RO, MP =4

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APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS (CONTINUED)

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
SALS, SSALR, SSALS	Shortened Approach Light System Simplified Short Approach Lighting System with Runway Alignment Indicator Lights Simplified Short Approach Light System	4 (CAT I) 1 (CPA)	
SCC	Systems Command Center	1	
SCIP	Surveillance and Communications Interface Processor		same as host facility
STARS	Standard Terminal Automation Replacement System	1 (ARTS II Replacement) A (ARTS III Replacement)	
STVSS	Small Tower Voice Switching System		same as host facility
TACAN	Tactical Air Navigation	1	
TCCC	Tower Control Computer Complex		same as host facility
TCS	Tower Communications System		same as host facility
TDWR	Terminal Doppler Weather Radar	1	
TMCC	Traffic Management Computer Complex		same as host facility
TMLI	Television Microwave Link Indicator		same as host facility
TMLR	Television Microwave Link Repeater		same as host facility
TMLT	Television Microwave Link Terminal		same as host facility
TMU	Traffic Management Unit	A	

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APPENDIX 1. PART A, FACILITY POWER SOURCE CODES: GNAS (CONTINUED)

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
TOWB	Tower Building	4 (Low and Intermediate Activity with non-radar approach control) **1** (Low and Intermediate Activity with radar approach control, major activity) **1** (All towers over 65 feet in height (cab floor) with elevator)	
TRACO (TRACON)	Terminal Radar Approach Control Facility	1	
TWEB	Transcribed Weather Broadcast		same as host facility
VASI	Visual Approach Slope Indicator	4	
VOR	Very High Frequency Omnidirectional Range	D	
VOT	VHF Omnidirectional Range Test	4	
VSCS	Voice Switching and Control System		Same as host facility ,
WAAS	Wide Area Augmentation System	**TBD**	

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APPENDIX 1. PART B, FACILITY POWER SOURCE CODES: ARTCC

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
ACCC	Area Control Computer Complex	A	
ADAS	AWOS Data Acquisition System	A	
AMCC	ARTCC Maintenance Control Center	A	
ARTCC	Air Route Traffic Control Center	A	
AWP	Aviation Weather Processor	A	
BUEC	Back-up Emergency Communications	A	
CCCH	Central Computer Complex Host	A	
CCMS	Central Computer Monitoring System	A	"CPU only"
CCTV	Closed Circuit TV	1	
CDC	Computer Display Channel	A	
CFCC	Central Flow Control Computer	A	
CHILR	Chiller System	1	
CTRB	Center Building	1	
CTS	Coded Time Source	A	
CUE	Computer Update Equipment	A	
CWP	Central Weather Processor	A	
DARC	Direct Access Radar Channel	A	
DCC	Display Channel Complex	A	
DCCR	Display Channel Complex Replacement	A	
DLP	Data Link Processor	A	
DMN	Data Multiplexing Network	A	
DMUX	Data Multiplexer	A	
DRG	Data Receiver Group	A	
DSR	Display System Replacement	A	
DSRCE	Down Scoped Radio Control Equipment	A	
DYSIM	Dynamic Simulator	A	
DVRS	Digital Voice Recording System	A	

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APPENDIX 1. PART B, FACILITY POWER SOURCE CODES: ARTCC (CONTINUED)

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
EARTS	En Route Automated Radar Tracking System	A	
EOF	Emergency Operation Facility	1	
ERMS	Environmental Remote Monitoring Svstem	TBD	
FAATSAT	FAA Telecommunications Satellite	TBD	
FAB	Center Fan and Blower Svstem	1	
FDEP	Flight Data Entry and Printout Equipment	A	
FDIOC	Flight Data Input/Output Center	A	
FOTS	Fiberoptic Transmission Svstem	A	
FSDPS	Flight Service Data Processing Svstem	A	
GOES	Geostationary Operational Environmental Satellite Svstem	A	
HCVR	High Capacity Voice Recorder	A	
LFDS	Large Facility Demarcation System	A	
LINCS	Leased Interfacility NAS Communications Svstem	1	UPS provided by Lesser
MPS	Maintenance Processing System	A	
NADIN	National Airspace Data Interchange Network	A	
NRCS (NARACS)	National Radio Communications System	1	
NXRAD (NEXRAD)	Next Generation Weather Radar	A	
OCC	Operational Control Center	TBD	
PAMRI	Peripheral Adapter Module Replacement Item	A	
RCAG	Remote Center Air/Ground	A	
RCE	Radio Control Equipment	A	
RCIU	Remote Control Interface Unit	A	

Power Source Code Definitions:
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APPENDIX 1. PART B, FACILITY POWER SOURCE CODES: ARTCC

FACILITY TYPE	DEFINITION	POWER SOURCE CODE	COMMENTS
RCLT	Radio Communications Link Terminal	A	
RMLT	Radar Microwave Link Terminal	A	
RRWDS	Radar Remote Weather Display System	A	
RMSC	Remote Monitoring Subsystem Concentrator	A	
RUMS	Remote User Monitoring System	1	
TDS	Telecommunications Demarcation **Svstem**	A	
TM-U	Traffic Management Unit	A	
UNCS		1	UPS provided by lessor
VEARS	**VSCS** Emergency Access Radio **Svstem**	A	
VSCS	Voice Switching and Control System	A	
VTROL	Center Environmental Control **Svstem**	1	
VTS	Voice Transmission Switch	A	
WAAS	Wide Area Augmentation System	TBD	
WMSC	Weather Message Switching Center	1	

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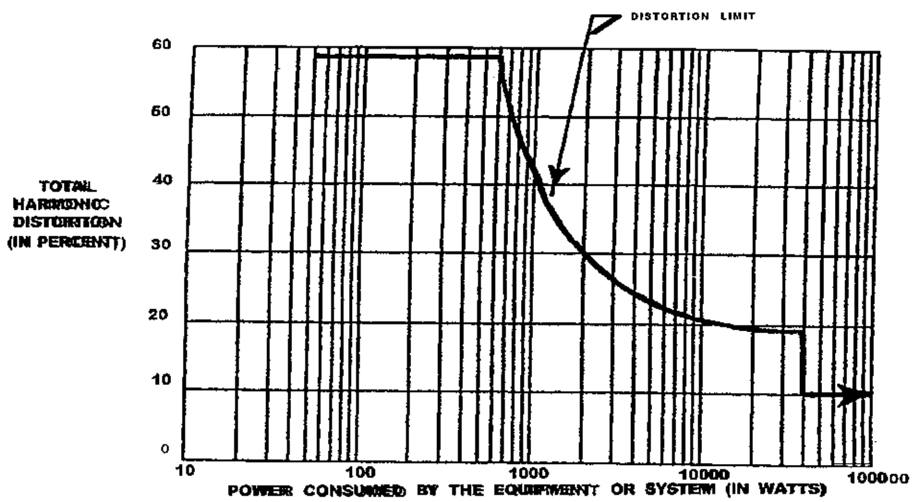
APPENDIX 2. CURRENT DISTORTION GUIDELINES



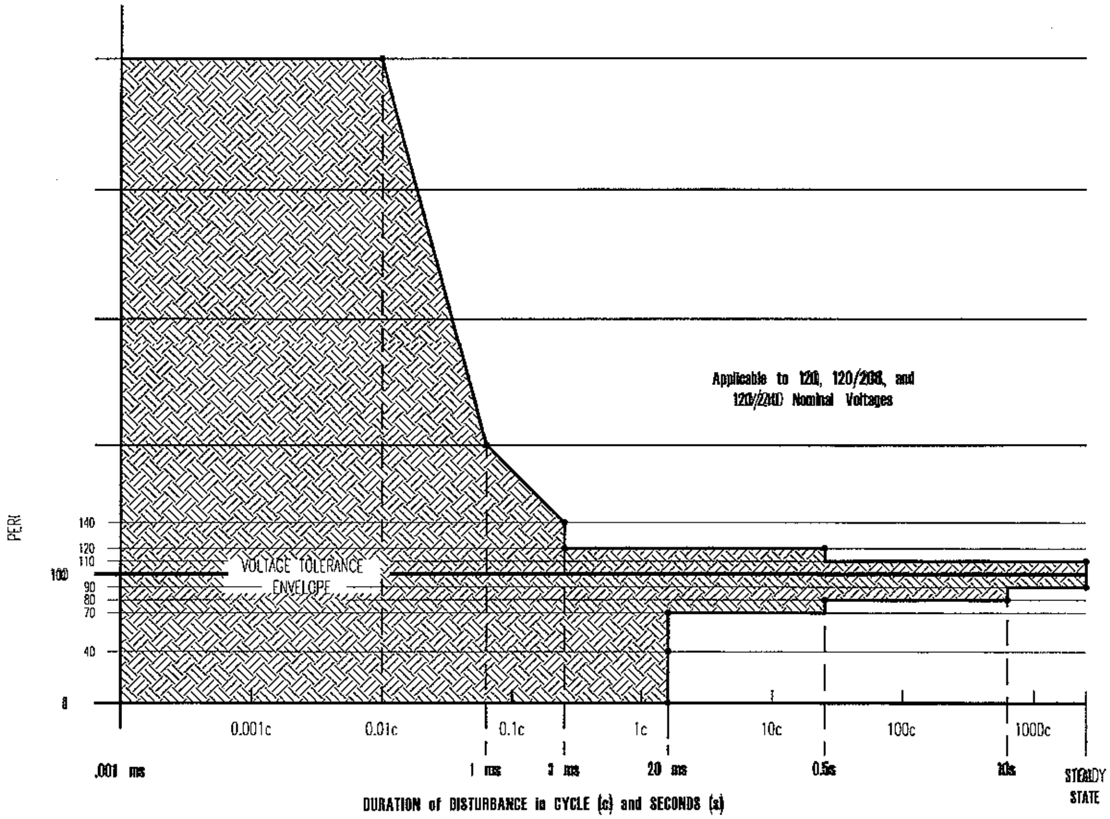
Distortion as a Function of System Load

Current Distortion as a Function of System Load

APPENDIX 3: POWER CRITERIA

GRAPH 1. NEW CBEMA CURVE

SUPPLY VOLTAGE-TOLERANCE ENVELOPE
for INFORMATION TECHNOLOGY EQUIPMENT
REVISED FEBRUARY 1996



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APPENDIX 3: POWER CRITERIA (CONTINUE)

TABLE 1. INPUT POWER CHARACTERISTICS

PARAMETERS	RANGES
Voltage Regulation	± 10%
Frequency variation	± 0.5 Hz
Frequency rate of change	1 Hz/sec
3Ø Phase voltage unbalance ±	5%

This table was extracted from specification FAA-G-2100F, Electrical Equipment General Requirements, page 16, paragraph 3.2.1.2.1.

Reference Only Material

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